Metals and Alloys

THE MAGAZINE OF METALLURGICAL ENGINEERING

PRODUCTION · FABRICATION · TREATMENT · APPLICATION

FEBRUARY 1942

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R-140

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highlights OF THIS ISSUE...

Feature Articles

Noble Metals for Today's Products

About the only commercially-useful metals of which there is *as yet* no shortage are gold and silver. Shell (page 236) discusses their engineering properties and outlines their possible utility in today's product design, both as alloys and coatings.

Hardenability

All the recent switching of steel compositions and hunting for satisfactory low-alloy or no-alloy materials has emphasized the No. 1 importance of hardenability, from the metallurgical design viewpoint. Anomalous hardenability behavior may be related to segregation in the ingot, say Parke and Herzig (page 241) who also describe a test for measuring such segregation effects.

An Aid to Metallurgical Analysis

Metallurgical engineers, often in a position to urge the use of certain speedier analytical methods on their chemical colleagues, will be interested to read the description by Silverthorn and Curtis (page 245) of fast colorimetric analysis applied to the determination of manganese and chromium in steel.

More About "Chrom-X"

The experience of a large Canadian steel maker in the use of "Chrom-X" (exothermic chromium addition agents made from low-chromium ores) for the production of chromium alloy steels is now placed in the record by McDonald (page 249).

Electric Salt Baths for Treating Aluminum

Practically all our manufactured aluminum is at present being processed and used in aircraft work, and a large part of this is being heat treated. Santore's brief article (page 254) on the heating of large aluminum alloy aircraft parts and of rivets in modern electric salt bath furnaces is thus of timely interest.

Brake Drums and Materials Therefor

Modern vehicles—combat and otherwise—go faster and stop quicker than ever before. The service and requirements of brake drums are thus increasingly heavy, and it is helpful to have Smalley's (page 256) discussion and comparison of the various irons and steels that can be used as brake drum materials.

Metallurgical Engineering Digests

Reclamation in the Foundry

Shortages of critical metals can be eased through reduction in non-essential use, through substitution where sensible, and through conservation and reclamation. Buchanan (page 284) outlines methods of salvaging waste materials from foundry operations.

Rolling Mill Bearings

The more steel and non-ferrous metals we make, the more service our rolling mill bearings must give. A "composite" on page 286 discusses the application and maintenance of these vital components.

Aircraft Welding

Trends in the application and technique of gas, arc and resistance welding in the aircraft field are cited in an informative composite digest on page 298. Welding both of alloy steels and of light metals has expanded tremendously in this field.

Which Type of Cutting Tool?

Even with current restrictions on the use of high-tungsten tool steels, the metallurgical engineer still has considerable leeway in choosing among the various available cutting tool materials. St. Clair (page 308) appraises several types from the standpoints of hot hardness and toughness.

Hardening Die Steels Without Distortion

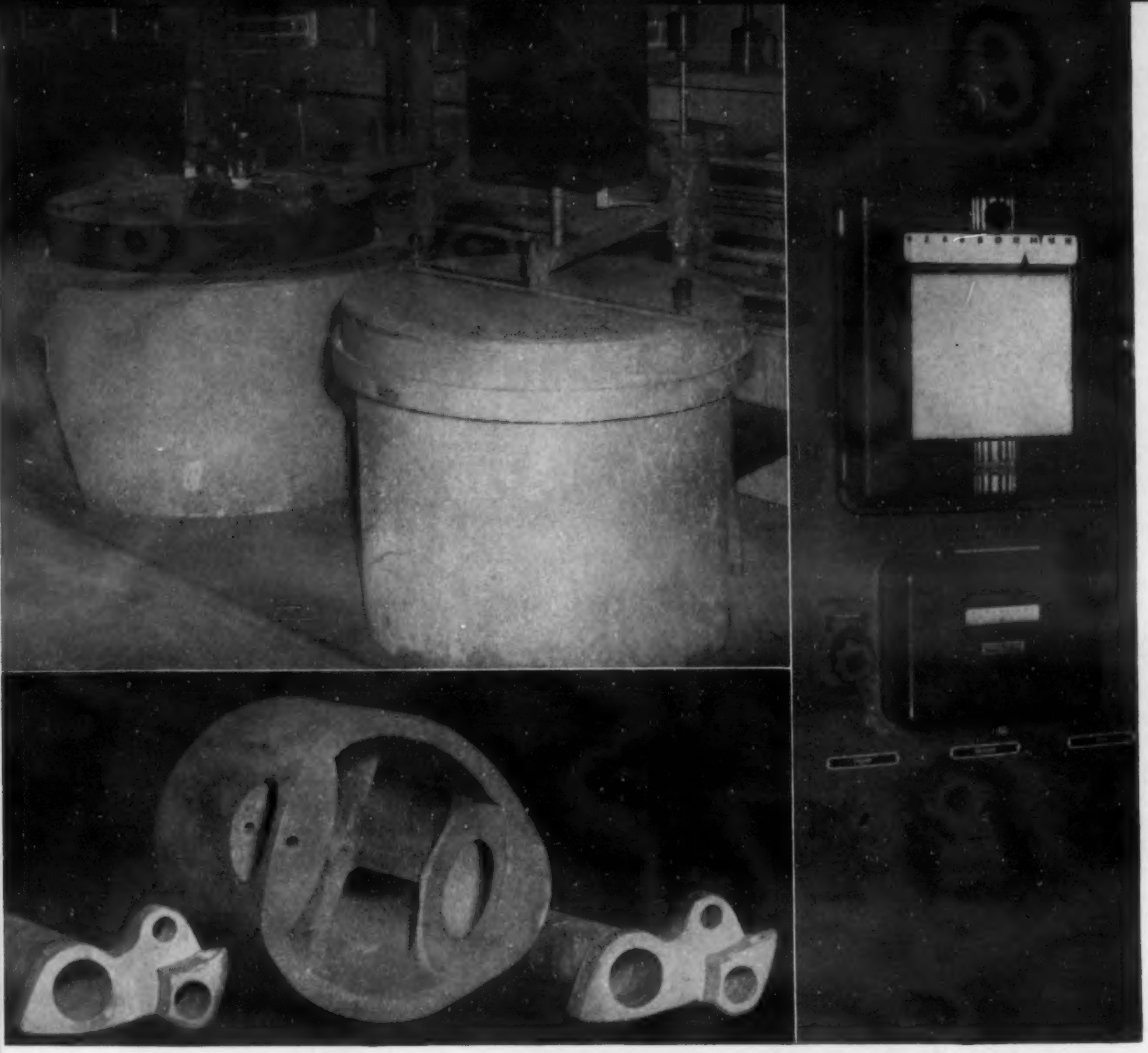
In these hectic days, with conversion "troubles" of one kind or another the rule rather than the exception, our "how-does-life-look-to-you?" level was raised about six units on learning from Butler (page 310) that the new air-hardening manganese-chromium-molybdenum die steels can be treated to return exactly to their original lengths after tempering.

Bearings and Surface Smoothness

The idea that *some* bearing surfaces should be *rough* has been gingerly introduced by a few engineers. This hypothesis and certain other aspects of the problem of bearing surfaces are discussed in a "composite" on page 322.

Armor Plate of Aluminum Alloy?

As though aluminum didn't have enough to do just now, someone in *Light Metals* (page 330) discusses its possible advantages as a material for duplex armor plate.



Top: Homocarb furnace (at left) in Cincinnati Shaper Co.'s heat-treat. Parts that cannot be quenched direct from Homocarb are cooled in L&N slow-cooling unit alongside.
Below: Machine-tool parts after Homo-Carburizing. Large piece in center is piston for hydraulic hold-down mechanism of steel shears. Small pieces on either side are pawl arms used on shapers.
Right: All controls for Homocarb furnace are on this factory-wired panel.

TOOL BUILDER'S CARBURIZING SOLVED BY HOMOCARB METHOD

Uniform case, reduced warp, few rejects — that's the Cincinnati Shaper Company's comment on their experience with the Homocarb Method of carburizing. It's based on months of experience gained since they turned to Homocarb. Pistons, pawls and ratchets, gears, shafts, splines and other carburized parts of "Cincinnati" Shapers, Shears and Press Brakes are included in their production, and indicate the high quality of heat-treatment maintained.

Homocarb succeeds because it enables the heat-treater to do away with guesswork; because it gives a greatly improved control of carburizing, by means of 4 controls:

1. Temperature. A Micromax Controller regulates heat-input to maintain the specified temperature — and the scientifically-designed Homocarb Furnace spreads heat uniformly through the load.

2. Quality of carburizing gas. This gas comes from chemically-constant Homocarb fluid; a precision, laboratory-controlled product developed for this special purpose.

3. Amount of carburizing gas. The heat-treater sets a knob for the desired amount of Homocarb fluid, and flow is metered accurately and continuously to meet the specification.

4. Time of Carburizing. Time of charging, rate of heating, soak temperature and time of operation are all recorded by Micromax. Analyzed in the light of results, the records help assure uniform, reproducible results.

For further details about Homocarb, ask for Catalog T-623.

Immersion Couple "At Home" With Micromax Pyrometer In Ohio Brass Foundry

Here's one of the foundryman's standard tools—the "Marshall-type" themocouple—at work in the foundry where it was born. Mr. Marshall was an Ohio Brass Co. engineer when he developed this useful device, and here we see an O.B. Co. foundryman using a Marshall couple and round-chart Micromax Pyrometer, to tell whether the brass in the ladle is at correct pouring temperature.

This form of thermocouple is only one of many improvements in pyrometry in which we have been privileged to participate with our customers. For a quick overall picture of the kinds of instruments which are available, we'd suggest a look at our catalogs. Tell us about your temperature-measuring problem, and we'll send the appropriate book.

"Watchman's-Eye" View of Furnace Temperature

When his rounds bring the watchman to Ohio Brass Co.'s foundry, he stops at the point from which this picture was taken, picks up a thermocouple, and plunges it into the furnace partly shown in the left foreground. The couple is connected to the round-chart Micromax, and from where he stands the watchman can see the big black arrow wheel around the dial and point to furnace temperature. If it reaches the correct temperature, the watchman goes immediately on his way; if not, he first gives the fuel valve a turn. But he never has to trot back and forth between furnace and pyrometer, thanks to the "dial like a town clock" which enables him to read this Micromax from a distance.

Jrl Ad ENT-0600C(38)

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Pearlitic Malleable Sanely Considered

From several points of view a pamphlet, "Report No. 1 on Sponsored Fellowship Investigations in Industry," whose title is, "The Commercial Market for Pearlitic Malleable Cast Iron," is of interest.

Technically, the question why a low-cost product, combining machinability, good strength, and adequate ductility for most uses, has not had more rapid commercial acceptance, certainly bears examination. Equally interesting is the scheme through which the pamphlet came to be written. The author, D. L. Boyes, made the study as a Master's Thesis at Massachusetts Institute of Technology, in the Department of Business and Engineering Administration, where he held an A. P. Sloan Fellowship for Executive Training, while on leave of absence from the Saginaw Malleable Iron Division of General Motors.

Thus the author approached the economic and business aspects of the case with a background of engineering information on, and experience with, the material under economic study. This is so unusual among economists as to call for comment and deserve approbation.

In a university thesis, an author seeks to record facts and doesn't have to pull any punches. A discussion of how far pearlitic malleable might replace steel forgings and castings would be embarrassing to the A.F.A., the A.S.M., or the A.I.M.E. One is hardly likely to find in such publications a reasoned estimate that nearly 30 per cent of steel forgings and 15 per cent of steel castings are of such section and properties that pearlitic malleable might be equivalent, competing, engineering material. Nor does one usually find in such publications a list of names of the producers of each type of pearlitic malleable.

The psychology of actual and potential users, who may not care to take a chance or to shift their practise one iota, is considered as true a limitation to rapid application as are the technical drawbacks of the requirement of small section, the propensity toward cracking, the lack of weldability, and the difficulty of straightening.

Boyes brings out that, as the properties and potentialities of pearlitic as an engineering material are better appreciated by designers, its use should grow. Just how the publicity can be had most effectively is a problem on which Boyes gives interesting discussion.

One feature not prominently brought out by Boyes is the relief the use of pearlitic malleable might bring to the forging and steel casting industries, both overloaded by pressure of war production. With the stopping of automobile production, the equipment of the malleable foundries will provide a lot of unused capacity. Even if new equipment were required, cupolas and converters for duplexing can be installed

Inland is Building Blast Furnaces To Help Win the War

We're building three huge blast furnaces to help win the war! They are a part of the government's program to provide more pig iron and to help overcome the shortage of steel scrap.

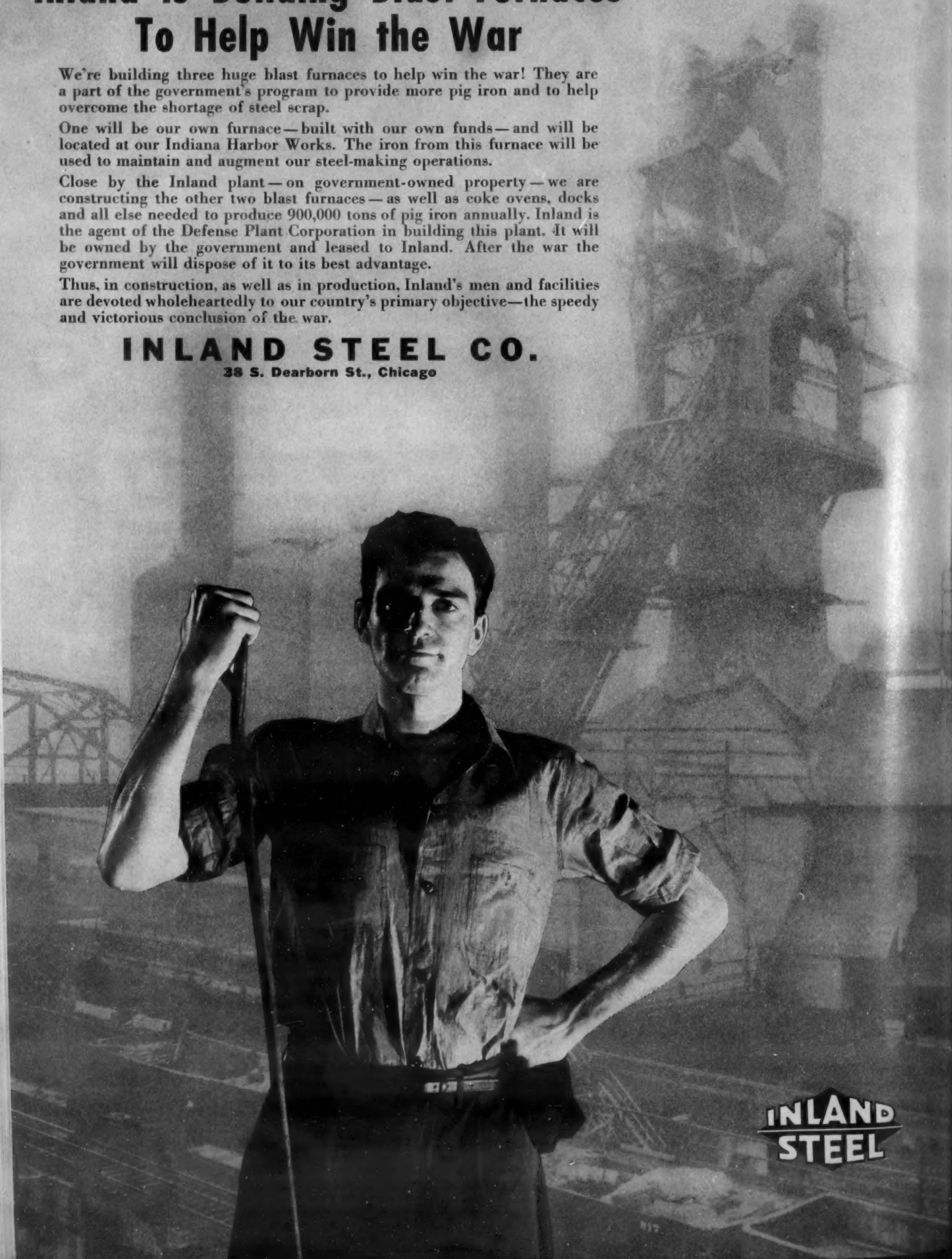
One will be our own furnace—built with our own funds—and will be located at our Indiana Harbor Works. The iron from this furnace will be used to maintain and augment our steel-making operations.

Close by the Inland plant—on government-owned property—we are constructing the other two blast furnaces—as well as coke ovens, docks and all else needed to produce 900,000 tons of pig iron annually. Inland is the agent of the Defense Plant Corporation in building this plant. It will be owned by the government and leased to Inland. After the war the government will dispose of it to its best advantage.

Thus, in construction, as well as in production, Inland's men and facilities are devoted wholeheartedly to our country's primary objective—the speedy and victorious conclusion of the war.

INLAND STEEL CO.

38 S. Dearborn St., Chicago



quicker than steel melting furnaces.

Even though a reader has no interest in pearlitic malleable, but is concerned with the marketing of something quite different, the method of approach will be of direct interest.

We are hoping that more metallurgical engineers will graft economic thought upon their technical base. Ultimately such a combination may correct the harm that New Deal economists, ignorant of, and apparently both unable and unwilling to grasp, the technical fundamentals, have done from their point of vantage in Washington. —H.W.G.

Manganese

In successfully meeting a critical situation thus far—sufficient supplies of ferromanganese for an output of nearly 83,000,000 tons of steel—the blast furnace industry and other interests deserve distinctive credit for the 1941 achievement. A total of 539,163 net tons of this ferroalloy was made last year, an increase of 13.8 per cent over the 1940 total, and a record. The average monthly production was 44,930 tons but this was exceeded during several months, particularly the 55,495 tons made in October.

That was when importation was not hampered. Outside of one outstanding case of private enterprise, the progress of plans and processes for utilization of low grade domestic manganese ore has been appallingly slow. There is no trouble in production if you can get suitable ore or sinter from working up low grade ores. There's the rub. Far too much manganese is still used in shell steel, when simple heat treatment of carbon steel will give the necessary properties. It has been simpler to use high manganese than to install heat-treating facilities, but that situation may change before shell producers are ready to cope with it.

The situation regarding this highly essential material has been encouraging. The cooperation of the metallurgical engineers of the country in demonstrating how manganese can be conserved or the quantity reduced has been an achievement. —E.F.C.

Electric Steel

Spectacular have been the advances made by the American electric steel industry in the last two years. Only by an examination of the official statistics of the American Iron and Steel Institute can this be appreciated.

The 1941 electric steel output of ingots and castings reached the impressive total of 2,920,849 net tons—a new record. Last year's total was 72 per cent in excess of the 1940 record and 183 per cent over that for 1939. Only once previous to 1939 did the total exceed 1,000,000 tons—1,065,603 tons in 1929. Twenty years ago the output was only about 500,000 tons.

Significant of the rapid increase in capacity of the industry in 1941 is the fact that the 1941 output exceeded the rated capacity as of Dec. 31, 1940, by over 334,500 tons.

The cause of this expansion is not far tc seek. The demand for high-grade aircraft, automotive, armor plate and other steels, for defense and war purposes has advanced by leaps and bounds. For the present emergency this expansion is heartening. —E.F.C.

- Production of aluminum and magnesium is reaching such large proportions that the recording of the output in pounds is unwieldy. This custom is almost as confusing as money expressed in billions. With the American output of both aluminum and magnesium now in the realm of hundreds of millions of pounds annually, we advocate in the future the conversion of these quantities into net tons in editorial discussions. For example, the prospective production of 400,000,000 lbs. of magnesium in the near future is much better expressed and comprehended as 200,000 net tons, especially when comparisons are made with the records in steel, pig iron and other materials.

Gold and Silver

by JOHN S. SHELL

Director of Research and Development,
Thos. J. Dee & Co., Chicago

With the major metals for the Victory program difficult to obtain in abundance, there is no scarcity of gold and silver. These metals and certain of their alloys have anti-corrosive properties and materials of this nature are necessary in certain military products.

The author calls attention to some of the alloys of gold and silver and discusses their properties and possible applications, either as coatings or as alloys, in today's products. The problem of relative costs is also dealt with.—The Editors.

PRIORITIES IN THE VICTORY PROGRAM have probably affected metallurgical engineers and their plants before any other industrial group and a glance at the list of materials on the priority list serves to emphasize more than ever before: (1) the importance of metals to national defense and (2) the inadequate supply of certain metals for defense.

A closer examination of the list of metals for which priorities have been declared indicates, probably by chance, a strong preference for corrosion resistant metals. Among the most stringent members in the group of restricted metals are nickel, chromium, cadmium, tin and zinc, all of which are extremely useful as thin coatings for the protection of less resistant metals. Aluminum, another corrosion resisting metal, is also a prominent metal on the

Silver alloy brazing of a radio-protection shield for an aircraft engine ignition system. Twenty-four brazed joints are made in each brass shield, with the quality and speed demanded in all aircraft manufacturing. (Courtesy: Handy & Harman. Photo by Sickles.)

in Wartime

priority list. For this reason, engineers, metallurgists and chemists are busily engaged in research investigations designed to develop substitute metals of a corrosion resisting nature; the noble metals are often offering the easiest solution to the problem.

Before the present emergency is ended it may develop that we are extremely fortunate in having large quantities of gold and silver available in this country, not for purposes of credit stabilization, but for metallurgical defense requirements. With reports on the alarming shortage of many metals constantly before us, the adequacy of our gold and silver supply has never been questioned.

The two noble metals, gold and platinum, are corrosion resisting materials *par excellence,* and this corrosion resistance does not depend upon the formation of a protective oxide coating. Possibly for this reason they are capable of providing a protective surface coating for base metals in much smaller quantities than many of the other corrosion resisting materials. It has been found possible to produce an electrolytic gold plate which, by visual observation, completely covers the base material, at a metal cost of about ½ cent per sq. in.

Design Properties of Noble Metals

In addition to their value as a protective coating, the noble metals and their alloys can be employed directly as engineering materials, as they have unusual physical as well as chemical properties. Construction engineers have often omitted the consideration of gold, platinum and silver or their alloys, even for small parts, because it has always been supposed that these materials were soft, weak, malleable metals. This is true of the pure metals, but in the alloyed form it is possible to produce combinations of gold with other metals which are hard, stiff and even brittle, and yet retain enough of the precious metal content to be truly corrosion resistant. It is also possible to produce gold alloys with a complete range of physical properties between these two extremes, and at the same time to vary the color from silver white, to green, through the red shades and even to a bright purple.

Hardness of Gold

Pure gold probably has a standard Brinell of 16 to 20 and a Baby Brinell of 25 to 27. In considering data on gold alloys, it is well to remember that the hardness values are almost always reported as Baby Brinell values, using a 1/16 in. ball and a 12.6-kg. weight. Theoretically this corresponds to a 10-mm. ball and a 500-kg. weight, but the standard 10-mm. ball requires too large a specimen for testing many types of products prepared from noble metal alloys. At the time that the Baby Brinell was adopted by the Bureau of Standards for the preparation of dental gold alloy specifications, the Vickers hardness tester and the superficial Rockwell tester were not generally available.

The range of possible hardness values starting with pure gold at a Baby Brinell of 25, may extend up to almost 300 for a heat-treated platinum containing wrought gold wire. If the required hardness need not exceed 260, the alloys can be fabricated by casting without cold working. Alloys can be prepared with a continuous range of hardness values between these limits and, fortunately, it is possible to obtain this entire range in compositions which will resist completely action by concentrated nitric, sulphuric, or hydrochloric acid solutions.

Other Physical Properties

The tensile strength limits of gold and its alloys extend from about 16,000 lbs. per sq. in. for pure gold in the cast condition to 175,000 lbs. per sq. in. for the platinum-gold alloys in the cold drawn heat-treated condition. There is no definite yield point exhibited by the stress-strain diagram for the gold alloys, and various methods are used in reporting yield strength or proportional limit. Using the modified Johnson method the proportional limit varies from less than 1000 lbs. per sq. in for pure gold to 125,000 lbs. per sq. in. for the stronger alloys. A value of 150,000 lbs. per sq. in. has been reported.

Elongation: Although gold is the most malleable, and probably the most ductile metal known, the elongation of gold and its alloys seldom exceed 35 per cent. This may indicate that elongation and ductility should not be considered synonymous. Values as high as 50 per cent have been reported for 18-karat and 14-karat alloys, but elongations exceeding 30 per cent are seldom found in the high strength, high fusing wrought gold alloys in the annealed state. These alloys are sufficiently ductile to be drawn into extremely fine wire and may be subsequently hardened by heat treatment. Rods prepared from alloys having a heat-treated hardness of Baby Brinell 300 can be drawn in the annealed condition (hardness about 200 and elongation 15 per cent) to wires of 0.001 in. in diameter with little difficulty.

Modulus of Elasticity: The modulus of elasticity of gold alloys varies from about 11,000,000 to, possibly, 19,000,000 lbs. per sq. in. but the majority of the high strength wrought wire alloys have a modulus of elasticity between 15,000,000 and 19,000,000, while most of the cast alloys have a modulus between 12,000,000 and 15,000,000 lbs. per sq. in. This means that the high strength gold alloys are in general about one-half as stiff as steel alloys of corresponding dimensions.

Torsion Tests: In the jewelry profession one of the main requirements for the noble metals is that they can be worked by hand into intricate shapes and designs. With the development of the new high strength heat treatable alloys this property is often a requirement even today. Hand working is being supplemented by the development of machines for preparing most articles, and this encroachment of the machine age has been felt in jewelry, but it is still necessary to have a satisfactory measure of the cold working ability of the noble metal alloys. There is some doubt as to whether the elongation tests give this information, and reduction in area tests are so unsatisfactory that they are seldom reported on gold alloys.

Torsion tests have been used as an indication of the workability or formability of gold alloys, and the number of turns per inch possible before fracture on a standard size specimen apparently gives a fairly satisfactory measure of their workability. This test is also valuable as an indication of the uniformity of the metal throughout a considerable length. By testing a specimen of uniform cross section in the torsion tester, any "hard spots" will show up immediately by a reduced number of spirals in that area.

Stiffness Tests: Stiffness tests on the Tinius Olsen stiffness tester are also becoming more extensively used, inasmuch as the bending capacity of these noble metal alloys is often an important factor in their fabrication as well as their subsequent function. The bending capacity is very rapidly reduced by heat treatment and this test offers an excellent opportunity for controlling the heat treatment within safe bending limits.

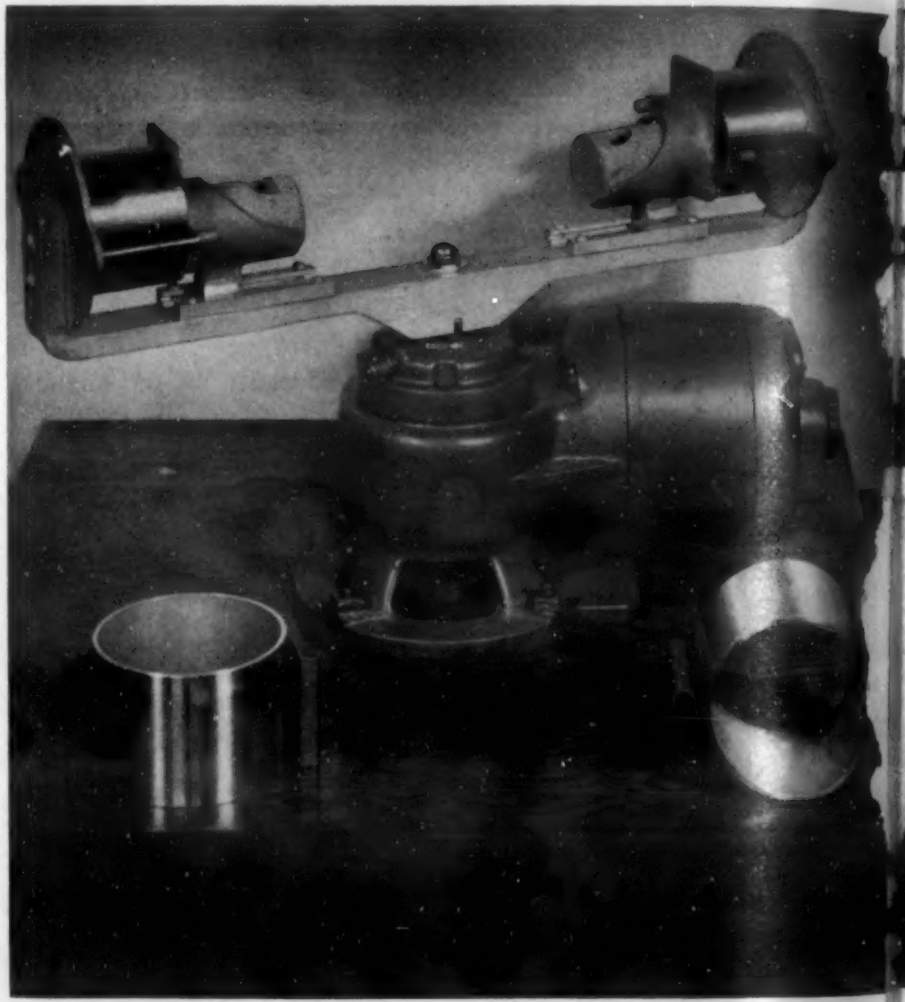
Specifications

The specification for gold wire, prepared for the American Dental Association by the Bureau of Standards, includes requirements for tensile strength of 150,000 lbs. per sq. in. for yield strength of 125,000 lbs. per sq. in. and an elongation of 4 per cent, with a gold and platinum metals content of 75 per cent. If this latter requirement is confined to gold and platinum the metal will resist boiling nitric acid, but if the palladium content becomes too high some action will be observed. A recent Federal specification has limited the palladium content to 4 per cent.

A specification for cast gold alloys in the cast-heat-treated condition calling for 100,000 lbs. per sq. in. tensile strength, 4 per cent elongation, 80,000 lbs. per sq. in. proportional limit and 75 per cent Au and platinum could be readily supplied.

Heat Treatment

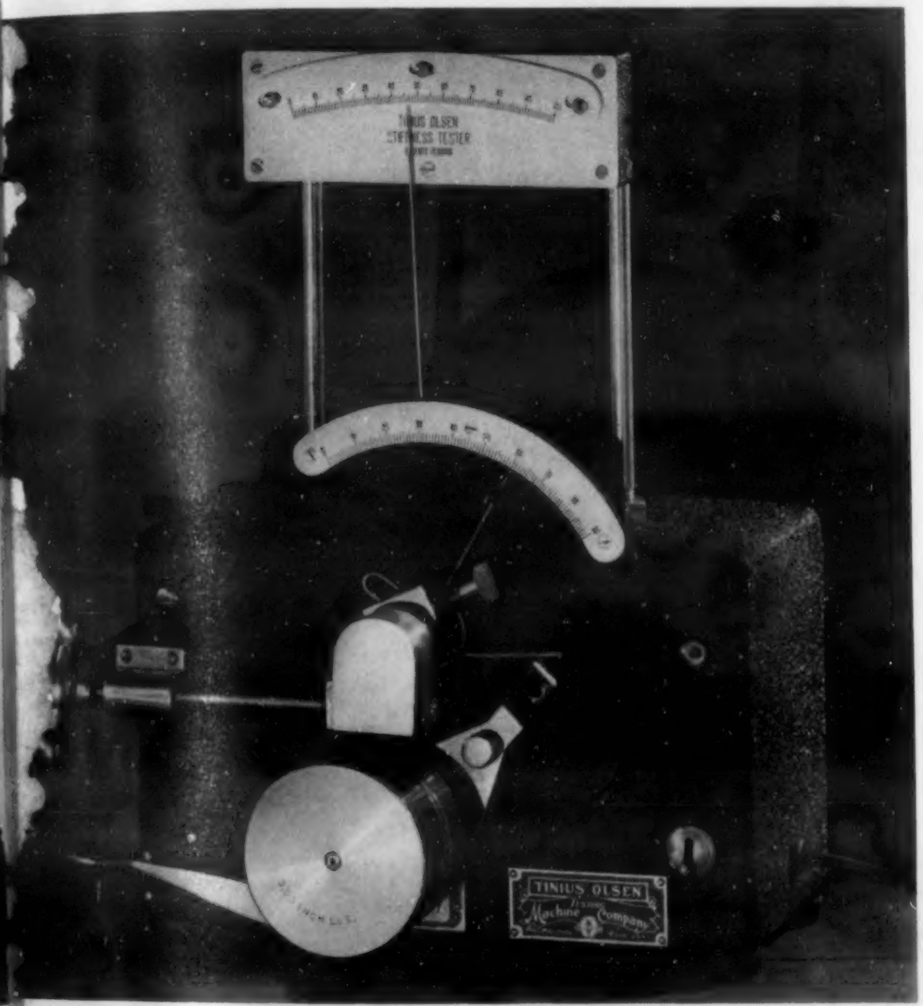
The ability of gold copper alloys to be heat treated has furnished great impetus to the use of gold alloys in many fields and the application of heat treatment to the gold-copper-platinum alloys in the dental field under rigid control has revolutionized the practice of dentistry for much of the higher type restorative work. Possibly some use had been made of the annealing of gold alloys by heating and quenching rather than slow cooling for many years but the general employment of scientific heat treatment of the gold alloys did not make much progress until Harder reported the work of some Russian investigators on the gold-copper alloys.



A motor driven centrifugal casting machine for casting gold, platinum and silver alloys. Castings are made at each end simultaneously. About 1 lb. of metal can be cast, and the casting process requires 3 to 5 mins.

It was found that the gold-copper alloys, especially in compositions corresponding to 18 K red were softened by heating to about 650 deg. C. (1200 deg. F.) and quenching, but were hardened by cooling slowly through a temperature range starting at about 360 deg. C. (680 deg. F.) and extending down to 200 deg. C. (390 deg. F.). The 18 K red gold became so brittle on extremely slow cooling that wire drawing operations were impossible and even slight bending might cause fracture. Upon reheating to 650 deg. C. (1200 deg. F.) and quenching this brittleness was removed and the wires could be drawn.

The change in physical properties was attributed to the formation of a gold-copper compound, AuCu, and another composition range responding to heat treatment corresponding to $AuCu_3$ was found. The AuCu compound corresponds to about 75 per cent Au and 25 per cent Cu, or 18 karat and the binary alloy of gold and copper of this composition is red in color, thus explaining the brittleness encountered in the 18-karat red jewelry alloys.



A Tinius Olsen stiffness tester. This instrument measures the force required to bend a specimen from zero to 90 deg. It has been used for standardizing heat-treating schedules with wrought and cast gold, silver and platinum alloys.

X-ray investigation has since shown that this compound, AuCu, consists of a preferred orientation of the copper atoms in the lattice to form a face centered tetragonal system from the normal face centered cubic system of the solid solution. The solid solution is stable at the higher temperatures and the tetragonal system starts to form at about 400 deg. C. (752 deg. F.) It has also been found that numerous other binary systems employed in gold alloys such as gold-platinum and palladium-copper have crystal transformations inducing changes in physical properties.

Fabrication and Casting of Noble Metals

Articles can be fabricated from gold and silver alloys by the usual methods of rolling, stamping, spinning and drawing as readily as with brass or aluminum. They can be cast more readily than iron or steel, because of the lower melting point, and more readily than brass or aluminum because of the decreased tendency toward oxidation. Soldering and welding can be employed with great ease.

The resistance to oxidation of the noble metals extends to high temperatures, even up to the melting point and above. For this reason the noble metals, and many of the alloys can be melted with gas-air blow pipe readily, with relatively little precaution against oxidation except a thin layer of flux. This makes it possible to produce articles of gold alloys by a type of casting process not generally used in the metallurgical industry. This is a simple but efficient procedure, using the disappearing wax technic.

A wax model is made of the object required. Wax sprues are attached and the entire assembly is covered with the mixture of plaster of Paris, ground silica and water. After the plaster has set, a cup is cut in this material, which connects with the sprues. The metal is melted and forced into the sprues, either by air pressure, suction, or centrifugal force. After solidification the plaster of Paris can be removed and the article will be reproduced in the gold alloy. When a number of objects of the same form are desired, a permanent mold may be prepared into which wax can be flowed or molded. This method is now being used to prepare small articles weighing one or two ounces, or less, in commercial quantities for industrial purposes from gold and silver casting alloys.

Soldering and Welding

Because of the freedom from oxidation at high temperatures, noble metals can be readily soldered with "hard solders." These solders are alloys of the noble metals and are thus high strength materials (90,000 lbs. per sq. in. after heat treating.) They can be prepared with compositions which insure their inertness to the action of concentrated boiling mineral acids. The solidus of the melting range is seldom below 760 deg. C. (1400 deg. F.) so that the finished product may be employed at relatively high temperatures without danger of melting the joining material.

By a carefully controlled technic the metals can be joined by casting a union metal directly into the joint without solder or flux. This union metal may have practically the same fusing range as the original metal and excellent joints are obtained which show strengths approaching that of the parent metal.

Another of the remarkable properties of gold is that it can be cold welded with only slight pressure and this welded metal has considerable strength. Gold foil has been hand malleted into solid specimens which have remarkably high tensile strengths and, by placing a sheet of platinum between two sheets of gold, a hammered foil specimen can be prepared from this material with a tensile strength as high as 60,000 lbs. per sq. in. and a Baby Brinell of 90. Pure gold foil pressure welded specimens may reach as high as 48,000 lbs. per sq. in. with a Brinell of 65.

Corrosion Resistance

The corrosion resistance of gold alloys depends upon the content of the corrosion resisting components, but according to Tammann, this resistance is dependent upon the relative number of atoms of the corrosion resisting metal rather than the weight percent. When the ternary alloys of gold, copper and silver are considered, an interesting condition develops. One atom of gold to one atom of copper (197.2 parts of gold to 63.6 parts of copper) is a little over 75 per cent or 18 karat, but with gold and silver (197.2 parts gold to 107.9 parts silver) the percentage is about 65 per cent or 15.5 karat.

This indicates that alloys high in silver will be more resistant to corrosion than those high in copper with the gold content the same in each case. Alloys high in silver tend to be greenish in color, while those containing a high copper content are red, and this may be the deciding factor in jewelry production. The copper alloys are higher in strength and hardness than the silver alloys, which may be the deciding factor in industrial work. When cost, corrosion resistance, strength and color are to be considered, the problem of producing the most efficient and economical alloy for a particular purpose becomes rather complex.

Cost of Noble Metals

The cost of the noble metals is an economic factor which can often be overcome to some degree by their reclaim value. Gold at the present (Sept. 15, 1941) government price of $35.00 a troy ounce is about $510.00 per avoirdupois pound. (14.583 troy ounces equals 16 avoirdupois ounces or one avoirdupois pound.) A manufacturer's charge for alloying, or for processing into sheet, wire, or rod will have to be added to the cost of the metal. With a reclaim value of about $490.00 to $500.00 per lb. depending upon the gold content, the net cost to the user is only about $10.00 to $20.00 a pound, (plus the processing charge) for a corrosion resistant metal of the highest quality. Platinum is about the same price as gold at the present market (Sept. 15, 1941.)

At the present open world market (Sept. 15, 1941) silver is about $5.35 per avoirdupois pound. (This price should not be confused with the special United States government price of 77.75 cents per ounce which applies only to *American mined silver*) with a reclaim value of $4.50 to $4.75 for clean scrap. This provides a material with a net of well under $1.00 an avoirdupois pound. Considering the cost of many base metals, which may be between 50c to $1.00 a pound with no reclaim value, it is obvious that silver with its added corrosion resistance can be used economically in many places.

Summary

In small installations where corrosion resistance, high strength, ease of soldering or welding, ease of working or casting, are the deciding factors, gold alloys may be required. If resistance to corrosive atmospheres at high temperatures is required, pure gold or platinum may be the solution to the problem. Where complete resistance to the action of mineral acids (except aqua regia) is required, gold alloys of 18 K or greater, or platinum may be employed. If the corrosive conditions are not as rigid, lower karat gold alloys or silver may be employed.

Where protective coatings are necessary the noble metals may provide the desired protection, and gold, silver and platinum may be considered when priorities in the defense program make a change in materials necessary.

The author will welcome inquiries regarding the physical and chemical properties of the noble metals and their alloys where special engineering or manufacturing problems are encountered which indicate their usefulness.

Hardenability of Steel

Dendritic Segregation a Factor

by ROBERT M. PARKE and ALVIN J. HERZIG
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In appraising and selecting engineering and machinery steels, hardenability is with increasing frequency the most important "property" considered. Although hardenability can usually be evaluated on the basis of composition, grain size, hardening temperature, quenching rate, etc., there is an occasional steel of anomalous behavior. The possible relation of dendritic segregation in the ingot to such behavior is discussed, and a test for segregation described in this article.—The Editors

Analysis of the property of hardenability in steel has reached a point where predictions based on our present fundamental knowledge of that property can be regarded with some confidence. This confidence is evident in the wide prevalence of composition and grain-size specifications in applied metallurgy to describe the hardenability of a steel for a given purpose. However, there is the occasional steel of anomalous behavior, the hardenability of which cannot be precisely predicted on the basis of composition as given in trade specifications, grain size, hardening temperature, quenching practice, surface condition, and so forth. In fact, the technique of hardening in the laboratory is now so controlled that this anomalous behavior of certain heats of steel may be safely ascribed to characteristics of the steel rather than to conditions imposed in the hardening operation.

Surely, the inherent properties of a steel can be fully accounted for by a complete definition of its chemical composition and its physical state. The explanation of the anomalous instances of hardenability seems to rest then in the more complete definition of composition and physical state.

Considerable attention is being given to the detection and estimation of elements in steel other than those normally included in steel specifications of commerce. There are reasons to believe that in these efforts part, if not all, of the explanation of discrepancies in hardenability may be found. There is also reason to believe that our common description of the physical state of steel is inadequate. In addition to grain size, which now constitutes our principal concern in the relation between the physical state and hardenability, the degree of heterogeneity which arises from dendritic segregation in the ingot ought to be considered in describing the physical state of steel.

Relation Between Segregation and Hardenability

Several investigators have indicated that there is some relation between segregation and hardenability. The general opinion is that better hardenability is associated with better homogeneity. This statement actually requires qualification in practical cases. Whereas it is widely accepted that non-metallic inclusions initiate the transformation of austenite to pearlite in carbon steels, in alloy steels transformation is observed to be initiated more often than not in areas quite free from non-metallic inclusions. When it is recalled that the regions high in inclusions will also be high in alloying elements, it is obvious that

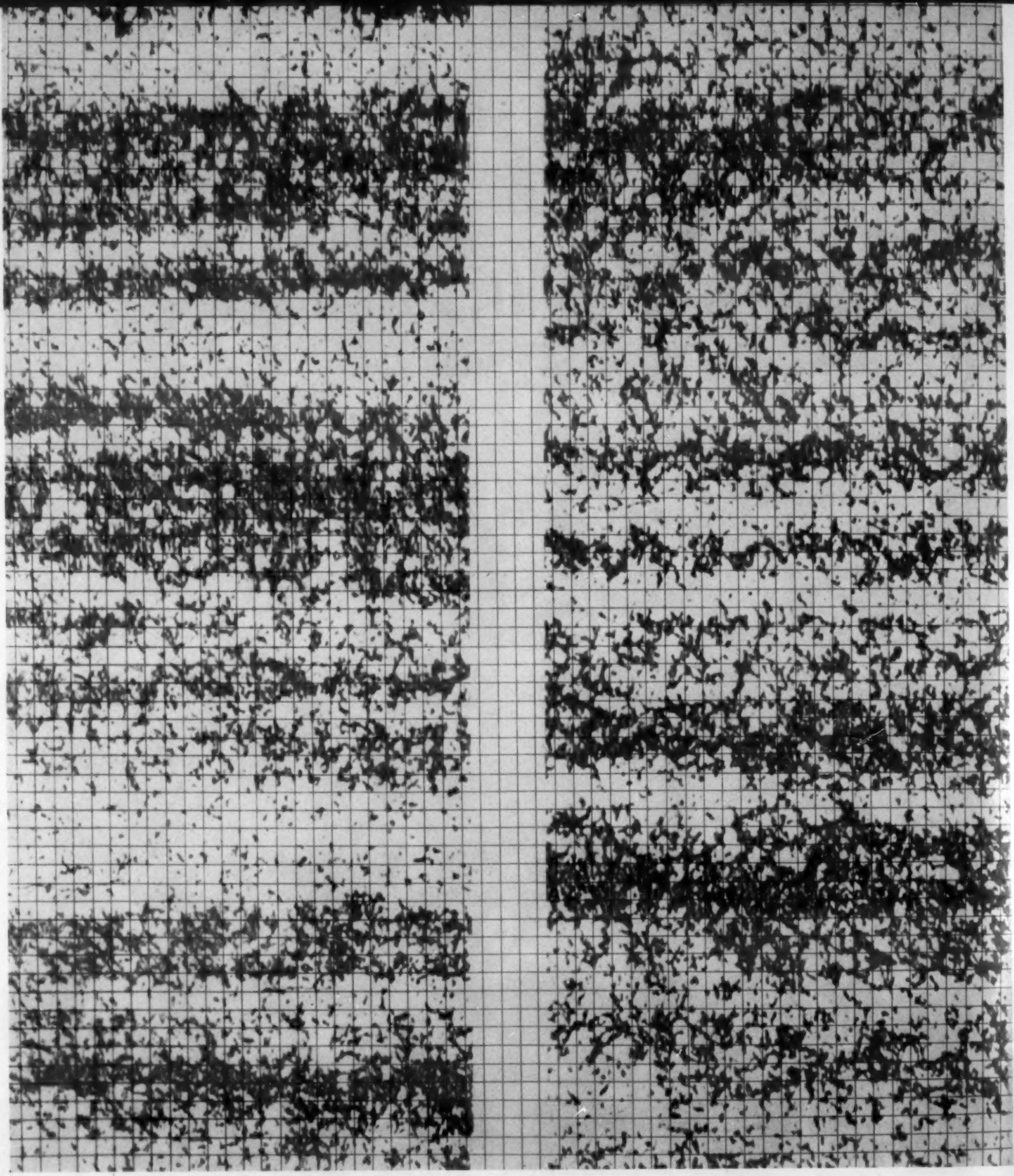


Fig. 1. The percent of austenite transformed in a given time in each band may be determined by imposing a grid on a photograph of the structure and estimating the percent of transformed austenite in each square.

the nucleating effect of inclusions may be offset by the greater amounts of alloy in these areas. In such circumstances, segregation may enhance rather than detract from hardenability. It is believed that progress in understanding the relationship between segregation and hardenability is handicapped by the lack of a method of measuring the extent of heterogeneity. The purpose of this article is to describe a method of determining the degree of microscopic heterogeneity of steel and to express it in such terms that the relationship between the degree of microscopic heterogeneity and hardenability may be examined.

The distance between the centers of a high-alloy region and the adjoining low-alloy region in a segregated steel is a matter of a few thousandths of an inch. Thus, it appears that chemical analytical methods are not directly applicable. Spectrochemical methods have shown promise but are not yet developed to the point where such small samples can be analyzed with confidence. Work along this line has been reported by Barker.[1] It should be pointed out, however, that even a full knowledge of the composition of the high- and low-alloy regions would not completely define the relation between segregation and hardenability.

Any direct relationship between microscopic segregation and hardenability must be based primarily on the occurrence within the steel, through segregation, of portions having critical cooling rates greater and less than the critical cooling rate of the average composition. It is logical therefore to base a test for segregation on the direct determination of the time for 50 per cent of the austenite to transform in each of these two portions of the steel, when transformation takes place at temperatures in the region of the nose of their S-curves. It appears that a relationship between these times could be selected which would measure the degree of segregation as far as its effects on hardenability are concerned. Such a method has been found useful in the laboratory of the Climax Molybdenum Co., in an investigation of the relationship between hardenability and segregation in steel.

A Test for Segregation

In conducting such a test for segregation, the temperature at which transformation of the bands is to be determined should be selected with care. In steels of low hardenability it is rather difficult to follow the progress of transformation at the nose of the S-curve; therefore it is generally advisable to select a temperature somewhat above or below that of the nose. Some steels produce a certain amount of fine pearlite when cooled at rates just less than the critical cooling rates, but others, especially alloy steels, produce bainite under the same cooling conditions. For this test then, a temperature of 1100 deg. F. would be selected for steels which transformed largely to lamellar products on cooling through the zone of fast reaction rate; but, for steels transforming largely to acicular products when cooled at less than the critical cooling rate, a temperature of 850 deg. F. would be more suitable.

If samples of a segregated steel are isothermally-treated at either of these temperatures for various lengths of time and the resultant structures examined, it will be seen that some bands begin to transform before others. The per cent of austenite transformed in a given time in each band may then be determined by imposing a grid on a photograph of the structure and estimating the per cent of transformed austenite in each square. An example of such a grid is shown in Fig. 1. The grid should be read in rows parallel to the bands in the steel.

If the transformation of austenite is in a temperature region where the reaction is initiated at grain boundaries, then the length of the rows of the grid must be several times the average grain diameter so that the different rates of transformation within a grain may not confuse the determination of the rates in different bands. By plotting the per cent austenite transformed in each vertical row against distance at right angles to the bands, the wave-like curve in Fig. 2 is obtained. Each peak of the curve gives the per cent of transformed austenite in a low-alloy region, while each valley gives the per cent of transformation in a high-alloy region for the same time at constant temperature. The average of the peaks may be taken as the per cent of transformed austenite in the low-alloy regions, and the average of the valleys represents the per cent transformed in the high-alloy regions.

Fig. 2. Average per cent of austenite transformed in each row parallel to the banding.

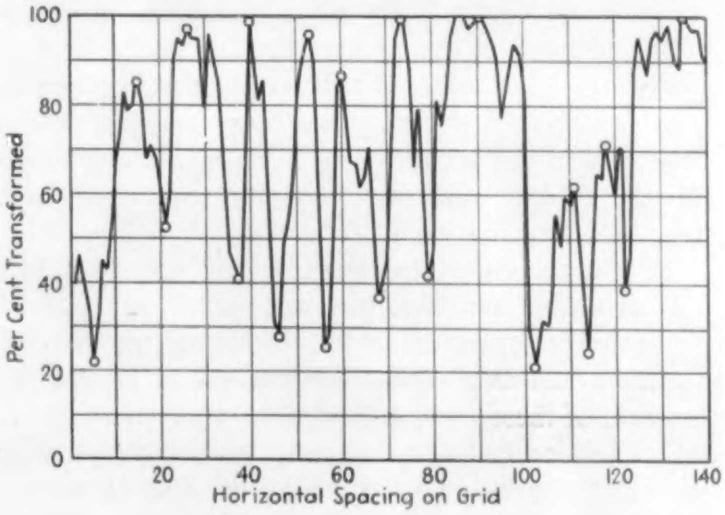
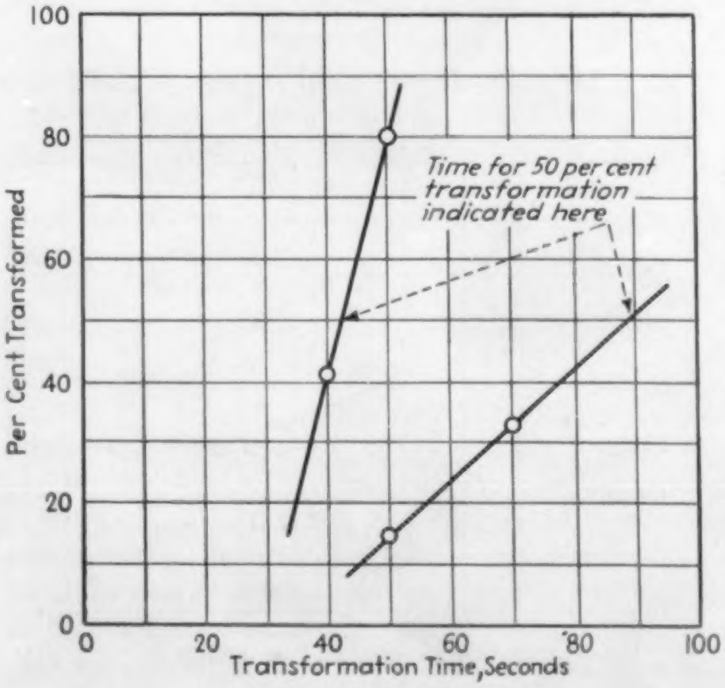


Fig. 3. Per cent of austenite transformed versus transformation time. Diagram for estimating 50 per cent transformation in high and low regions.



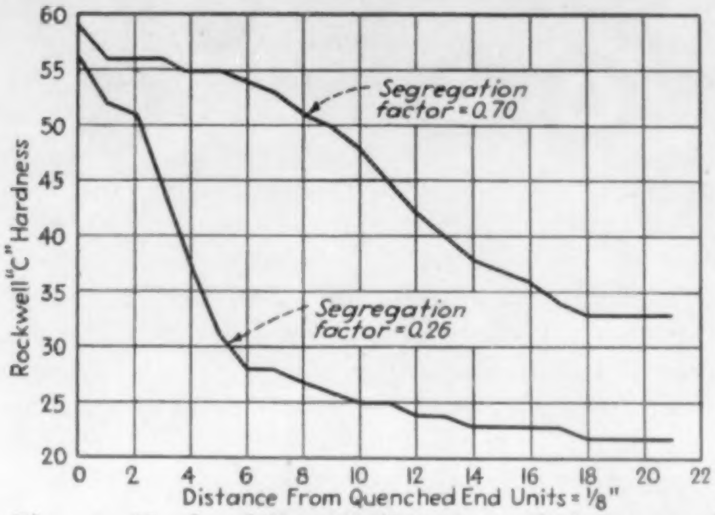


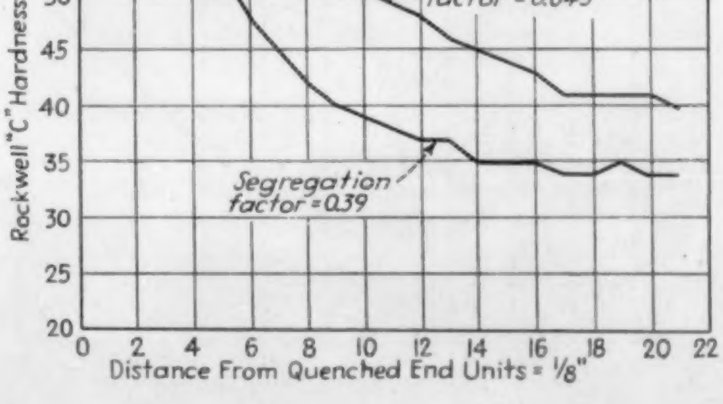
Fig. 4. Hardenability of T1340 steel before and after homogenizing.

If the per cent transformed in each of the two extreme regions is plotted against time at constant temperature, a curve may be drawn which permits estimation of the time for 50 per cent transformation in both the high- and low-alloy regions, as in Fig. 3. The difference in these times, divided by the average time, has been arbitrarily taken as the *segregation factor.* Thus, a perfectly homogeneous steel would have a segregation factor of zero, while the factor for the extreme case of segregation would approach two as a limiting value.

In the process of hot-working an ingot to a bar, the dendrites are stretched out into thin rods of polygonal cross-section. In examining the banded structure metallographically on a plane parallel to the axes of these rods, it is apparent that such a plane selected at random will frequently fail to pass through the center, or lowest-alloy region, of some of the intersected rods but will always pass through the high-alloy region of each rod intersected. Therefore, the grid should traverse as many bands as possible to insure that a representative structure has been examined. Even so, the time for 50 per cent transformation of the low-alloy regions will generally be determined as too long. This error may be reduced by selecting only the taller peaks.

This is a somewhat cumbersome test, but nonetheless it seems at this time to be the most direct means for reducing dendritic segregation to a numerical expression.

Fig. 5. Hardenability of 4140 steel before and after homogenizing.



Applications of the Segregation Test

This test for segregation has been applied by the authors to several samples of steel. For example, a heat of S.A.E. T1340 steel, as-rolled, and of the following composition:

	Per Cent
Carbon	0.39
Manganese	1.87
Silicon	0.18
Sulphur	0.018
Phosphorus	0.023
Molybdenum	0.013
Nickel	0.11
Chromium	0.06
Titanium	0.02

was found by the method described above to have a segregation factor of 0.70, while after holding 80 hrs. at 2310 deg. F. in vacuum the segregation factor was reduced to 0.26. The hardenability of this steel before and after the homogenizing treatment is shown in Fig. 4.

Another example of the application of this test is found in two heats of S.A.E. 4140 steel, which varied in hardenability as shown in Fig. 5. The composition of these two heats was as follows:

	A Per Cent	*B* Per Cent
Carbon	0.45	0.47
Manganese	0.78	0.77
Silicon	0.24	0.27
Sulphur	0.029	0.035
Phosphorus	0.018	0.016
Molybdenum	0.22	0.19
Nickel	0.087	0.063
Chromium	1.11	1.00
Vanadium	0.030	0.022
Copper	0.11	0.10
Aluminum	0.07	0.07
McQuaid-Ehn grain size	7-8	7-8
Austenitic grain size		
1550 deg. F.	8-9	8-9
1625 deg. F.	9-10	9-10
1700 deg. F.	8	8-9

On the basis of these brief experiments it would appear that the solution of the broader problem of explaining anomalous instances of hardenability in steel will contain, in addition to a more precise statement of composition, the measure of segregation as a factor of physical state. It is also indicated that segregation will enter the problem in a more complex fashion than is considered in the statement that better homogeneity is accompanied by better hardenability.

References

[1] F. G. Barker, *J. Iron Steel Inst.*, Vol. 139, 1939, page 211P.

F. G. Barker, J. Convey and J. H. Oldfield. "The Application of Spectrographic Methods to the Analysis of Segregates," *Iron Steel Inst.*, Advance Copy, July 1941.

COLORIMETRY IN

Metallurgical Analysis

By R. W. SILVERTHORN and J. ALFRED CURTIS

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Publication of analytical methods in METALS AND ALLOYS *is unusual. Once in a while a method crops up that is such a time-saver and so much off the beaten path as to deserve bringing it directly to the attention of metallurgical engineers. Time saving is always important, doubly so under present conditions. This article describes a rapid, accurate colorimetric method for determining manganese and chromium in iron and steel using the spectrophotometer. Manganese and chromium can be determined on the same solution of sample with no preliminary separations in approximately 15 mins. and with an accuracy of about 1 per cent. Procedures are given for the analyses of various types of iron and steel.*

COLORIMETRIC METHODS of chemical analysis are fairly widely used, but their application in metallurgical determinations is quite limited, largely because of limited accuracy and interfering elements. However, colorimetric methods, which are characterized by the speed with which a determination can be made, may be effectively used in metallurgical analysis if the color measurement is made by a spectrophotometer. Until recent times this equipment has not been available in a cheap, rugged, usable form and has been a tool of physicists rather than analytical chemists.

An absorption spectrophotometer is an instrument designed to produce light of any single wave length, i.e., monochromatic, and to pass light of that wave length through a sample, which in analytical chemistry is usually a solution. The percentage of light passing through is measured.

While colors may be matched by the human eye, the modern instruments are simple, compact, highly accurate ones in which the absorption is measured by means of a photoelectric cell in connection with an electrometer or galvanometer. They can be operated by ordinary analytical chemists. White light is composed of light of different wave lengths or different colors. A solution appears colored owing to the absorption of certain wave lengths and the transmission of others. The amount of light absorbed is a function of the concentration of the colored component in the solution, and thus quantitative data may be obtained. The instrument used in this investigation, Fig. 4, was the Coleman D M Spectrophotometer and costs approximately $525.

One of the few colorimetric determinations, and that not widely applied, in metallurgical analysis is for manganese. Chromium is sometimes determined colorimetrically in steels but only when present in small amounts such as residual chromium. As is well known to steel works chemists, in the case of high chromium irons and steels the usual methods for manganese are extremely tedious, and often not too accurate. Usually the manganese must be oxidized, precipitated and filtered to separate it from the chromium, or the chromium has to be removed by chloride volatilization.

An accurate, rapid, colorimetric method which permits the determination of either manganese or chromium or both in plain carbon or alloy iron and steels without a preliminary separation of the manganese and chromium is available when the spectrophotometric method is employed.

Table I.—Analyses of Bureau of Standards Steel Samples for Manganese

Spl. No.	Weight Grams	Chromium Present, Per Cent	Manganese Present, Per Cent	Manganese Found, Per Cent	Difference, Per Cent
111	1.0	0.27	0.66	0.66	0.00
111	1.0	0.27	0.66	0.65	—0.01
20d	1.0	0.28	0.92	0.91	—0.01
72a	1.0	0.655	0.60	0.60	0.00
72a	1.0	0.655	0.60	0.59	—0.01
30c	1.0	0.977	0.71	0.71	0.00
106	1.0	1.29	0.48	0.48	0.00
106	1.0	1.29	0.48	0.48	0.00
73	1.0	13.93	0.28	0.28	0.00
73	1.0	13.93	0.28	0.28	0.00
101a	1.0	18.33	0.47	0.48	+0.01
101a	1.0	18.33	0.47	0.47	0.00
9c	1.0	0.007	0.67	0.67	0.00
122	1.0	0.032	0.51	0.51	0.00
4c	1.0	0.012	0.72	0.72	0.00
7c	1.0	0.019	0.56	0.56	0.00
50a*	1.0	3.51	0.29	0.28	—0.01
50a	1.0	3.51	0.29	0.27	—0.02

* Contains 18.23% W and .971% V.

Table II.—Analyses of Chromium Steels

Sample No.	Chromium Present, Per Cent	Chromium Found, Per Cent	Difference, Per Cent
1	0.27	0.28	+0.01
2	0.66	0.65	—0.01
3	0.98	0.98	0.00
4	1.29	1.30	+0.01
5	3.66	3.67	+0.01
6	4.58	4.60	+0.02
7	4.67	4.65	—0.02
8	5.57	5.52	—0.05
9	6.97	7.05	+0.08
10	8.36	8.34	—0.02
11	10.50	10.50	0.00
12	11.14	11.08	—0.06
13	13.93	13.90	—0.03
14	13.93	14.00	+0.07
15	18.33	18.40	+0.07
16	18.33	18.35	+0.02

Table III.—Analyses of Bureau of Standards Steel Samples

Sample No.	Weight, Gram	Chromium Present, Per Cent	Chromium Found, Per Cent
73	0.30	13.93	14.00
73	0.20	13.93	13.90
73	0.30	13.93	13.80
101a	0.20	18.33	18.35
101a	0.25	18.33	18.40
72a	1.00	0.655	0.65
72a	1.00	0.655	0.65
106	1.0	1.29	1.28
106	2.0	1.29	1.34
106	1.0	1.29	1.30
30c	1.0	0.977	0.98
30c	1.0	0.977	1.0
20d	1.0	0.28	0.28
20d	1.0	0.28	0.30
111	1.0	0.272	0.30

Manganese Determinations

General Consideration of Spectrophotometric Methods: A spectrophotometer is not a spectroscope, and consequently, it is not necessary to spend several months in training an operator or several thousand dollars in standards and standard curves. A good analytical chemist can learn to make all the necessary measurements in less than a week, provided that he has a dozen bottles of various Bureau of Standards' steel samples. An analyst need only preface the graphs shown in Figs. 2 and 3 for chromium and manganese for his own particular instrument.

The absorption curves with different wave lengths must be known so as to choose a particular wave length, preferably of high absorption, with as little as possible interference from other elements. If the absorption curves are not known, they can be determined and plotted, as shown in Fig. 1. The amount of manganese or chromium that is present in the solution is not critical. In the example shown the manganese corresponded to about 1.0 per cent on a 1-gram sample, and the chromium to about 10 per cent.

Determination of Manganese Absorption Curve: A solution containing potassium permanganate was placed in the spectrophotometer and examined at different wave lengths. The per cent transmission was plotted against the wave length. Curve A, Fig. 1, resulted. A wave length 575 millimicrons ($m\mu$), a point of high absorption, was chosen to make the standard graph. Chromium does not interfere with manganese at this wave length.

With National Bureau of Standards samples, 1-gram, the percentage absorption was determined and plotted on semi-logarithmic paper versus the percentage of manganese present. This gave the curve, 575 $m\mu$, shown in Fig. 2. The recommended procedure, given later in this paper, was followed. A single determination required about 12 mins.

Recommended Procedure for Manganese in Plain Carbon Steel: Transfer a one-gram sample to an Erlenmeyer flask calibrated to contain 500 ml. Add 30 ml. of Bright Larabee acid (see reagents at end of this section.) and heat until dissolved. Add 100 ml. of hot water, 10 ml. of 0.8 per cent $AgNO_3$ and bring to a boil. Add 10 ml. of 25 per cent $(NH_4)_2S_2O_8$ and boil exactly 1 min. Cool, dilute to the 500 ml. mark, mix thoroughly, and transfer a sample to the color comparison tube.

Set the wave length indicator of the spectrophotometer at 575 $m\mu$ and balance the instrument using distilled water as the reference solution. Introduce the sample and record the per cent transmission. Read the per cent manganese from the standard manganese graph, Fig. 2, 575 $m\mu$.

If a 0.5-gram sample was used, multiply the result by 2; if a 2-gram sample was used, divide by 2 etc.

A 1-gram sample can be used for manganese contents up to at least 1.0 per cent; above this use a correspondingly smaller sample.

Procedure for Cast Irons: Transfer the sample to a 250 ml. beaker, add 30 ml. of 1:3 HNO_3 and heat until dissolution is complete. Filter off the graphitic carbon, catching the filtrate in a calibrated 500 ml. Erlenmeyer flask. Wash with hot water and add 50 ml. of acid mixture (see reagents at end of this section) for cast irons. Dilute to 130 ml., add 10 ml. 0.8 per cent $AgNO_3$ and proceed as in the recommended procedure for manganese in steel.

Procedure for Chromium Steels: Weigh a 1-gram sample into a calibrated 500 ml. Erlenmeyer flask, add 15 ml. of 60 per cent $HClO_4$ and heat until dense fumes of $HClO_4$ are given off for 2-3 min. and the solution is a bright red. Cool somewhat, add 30 ml. Bright Larabee acid, 5 ml. 85 per cent phosphoric acid and boil for 2-3 mins. Add 10 ml. of 0.8 per cent $AgNO_3$ and 140 ml. of hot water. Heat to boiling and add 15 ml. of 25 per cent $(NH_4)_2S_2O_8$ and boil for 1½ min. Cool, dilute to 500 ml. and determine manganese as in the recommended procedure for plain carbon steel.

Procedure for Tungsten Steels: Transfer a 1-gram sample to a calibrated 500 ml. Erlenmeyer flask. Add 25 ml. of water, 5 ml. of H_2SO_4, 5 ml. of H_3PO_4 and heat until dissolution is complete. Then add 10 ml. of HNO_3 (Sp. gr. 1.20) and boil until the solution is clear. Add 10 ml. of 0.8 per cent $AgNO_3$, 140 ml. hot water and bring to a boil. Add 15 ml. 25 per cent $(NH_4)_2S_2O_8$ and boil 1½ mins. Cool, dilute to 500 ml., and proceed as in the recommended procedure for plain carbon steel.

Reagents:

Sulphuric acid, Sp. gr. 1.84
Nitric acid, Sp. gr. 1.20
Nitric acid, 1 part acid to 3 parts water
Bright Larabee acid, 100 ml. H_2SO_4, 125 ml. H_3PO_4, 250 ml. HNO_3, 525 ml. H_2O
Acid mixture for cast irons, 75 ml. H_3PO_4, 60 ml. H_2SO_4, 865 ml. H_2O
Silver nitrate, 0.8%, by weight, in water
Ammonium persulfate, 25%, by weight, in water
Perchloric acid, 60%
Phosphoric acid, 85%

Determination of Chromium

The absorption curves in Fig. 1 show that while 450 mμ is a described wave length for chromium, manganese will interfere, if present. It is possible, however, to correct for the manganese present, and the method for doing so is shown graphically in this paper.

Absorption Curve: A solution containing 0.384 gram of CrO_3 per liter was prepared and a transmittance curve constructed by plotting per cent transmission against wave length. Curve B, Fig. 1 resulted.

Standard Graph: The standard graph, Fig. 3, 450 mμ, was prepared in much the same way as already described for manganese but in this case the total absorption was due in part to chromium and in part to manganese. That due to manganese had to be corrected for in the manner described later. As in the case of manganese, Bureau of Standards samples were employed.

Fig. 1. Transmittance curves.

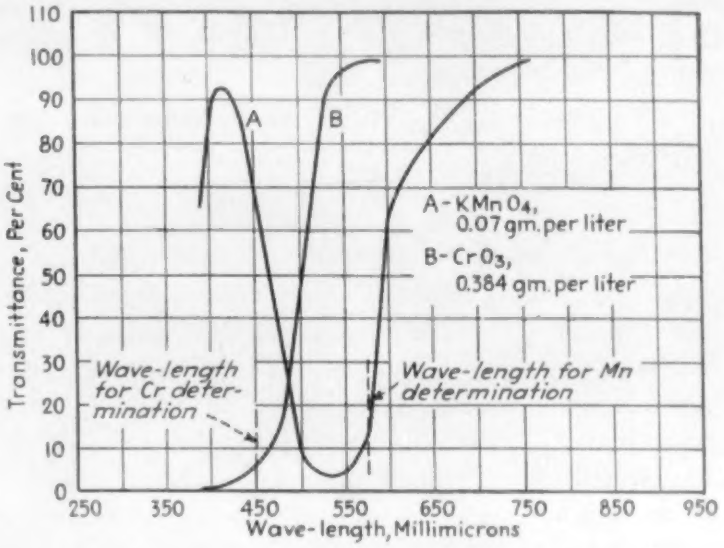


Fig. 2. Standard manganese graph.

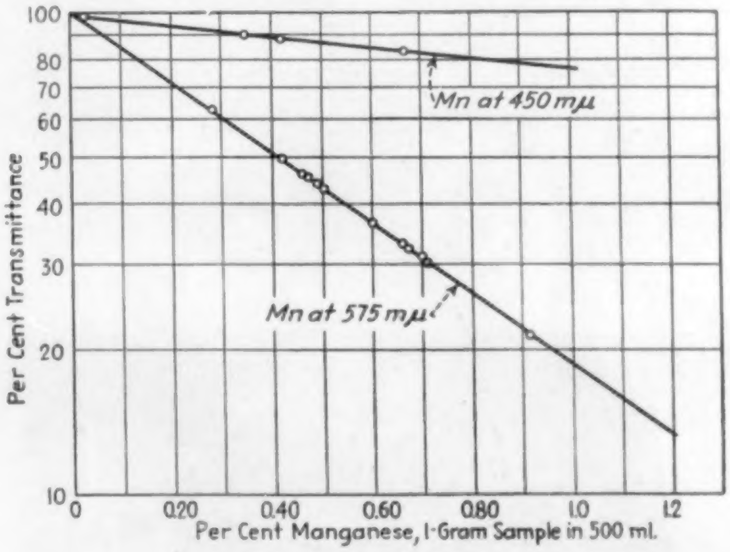
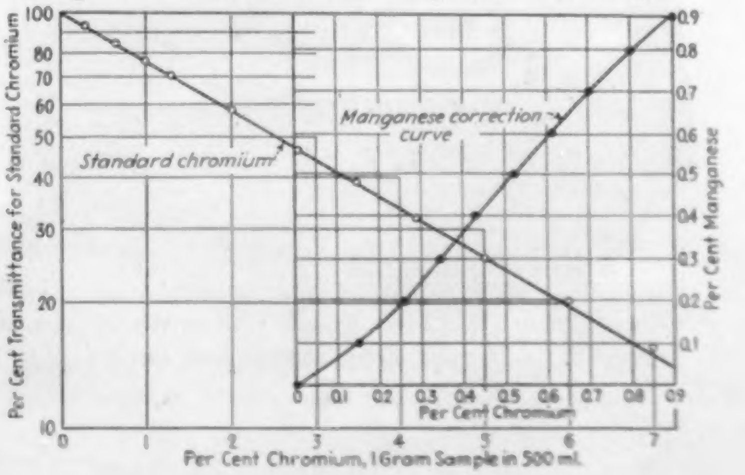


Fig. 3. Standard chromium graph.—450 Mμ.



Correction for Manganese: Because chromium is determined at a wave length of 450 mμ it is necessary to have a standard graph for manganese at this wave length. This is shown in Fig. 2. Manganese, however, is more accurately determined at 575 mμ than at 450, and at 575 mμ chromium does not interfere with manganese.

When the sample of solution is measured at 450 mμ the percentage transmission is governed by the chromium and manganese present, and is lower than had chromium only existed. Therefore, the standard chromium graph, Fig. 3, has been drawn from empirical data corrected for the manganese in the samples.

The method, therefore, is to dissolve the sample by the recommended procedure which follows, and to determine the total percentage transmission at 450 mμ. Read the "apparent" percentage of chromium from the abscissa. Determine the absorption at 575 mμ and read from Fig. 2 the corresponding percentage of manganese present. Then from the manganese correction curve, Fig. 3, read the correction to apply to the chromium determination for the manganese present. This correction is always a subtraction. The "apparent" percentage of chromium minus the correction for manganese equals the true chromium content.

Table II shows results, using the recommended procedure and the standard chromium graph.

The results in Table III indicate that the method is accurate.

Recommended Procedure for Chromium:

Transfer a sample to a calibrated 500 ml. Erlenmeyer flask. On steels higher than 7 per cent, use less than a 1-gram sample. Add 15 ml. 60 per cent perchloric acid and heat to fumes of $HClO_4$ and the solution is red. Let fume for 3-5 mins. Cool somewhat, add 30 ml. Bright Larabee acid, 5 ml. 85 per cent H_3PO_4 and boil 2-3 mins. Add 10 ml. 0.8 per cent $AgNO_3$ and 140 ml. of hot water. Heat to boiling, add 15 ml. 25 per cent $(NH_4)_2S_2O_8$ and boil for 1½ mins. Cool and dilute to the mark. Transfer a sample to the spectrophotometer and determine the absorption at 450 and 575 mμ. The method of calculating the chromium present has already been described.

Reagents:

Perchloric acid, 60%
Bright Larabee acid, 100 ml. H_2SO_4, 125 ml. H_2PO_4, 250 ml. HNO_3, 525 ml. H_2O
Phosphoric acid, 85%
Silver nitrate, 0.8%, by weight, in water
Ammonium persulfate, 25%, by weight, in water

Acknowledgements

The authors wish to acknowledge the permission of Battelle Memorial Institute, which financed the investigation, to publish the results. Grateful acknowledgement is also made to John D. Sullivan whose interest made this investigation possible and to Gerald H. Rothgery who performed some of the analyses.

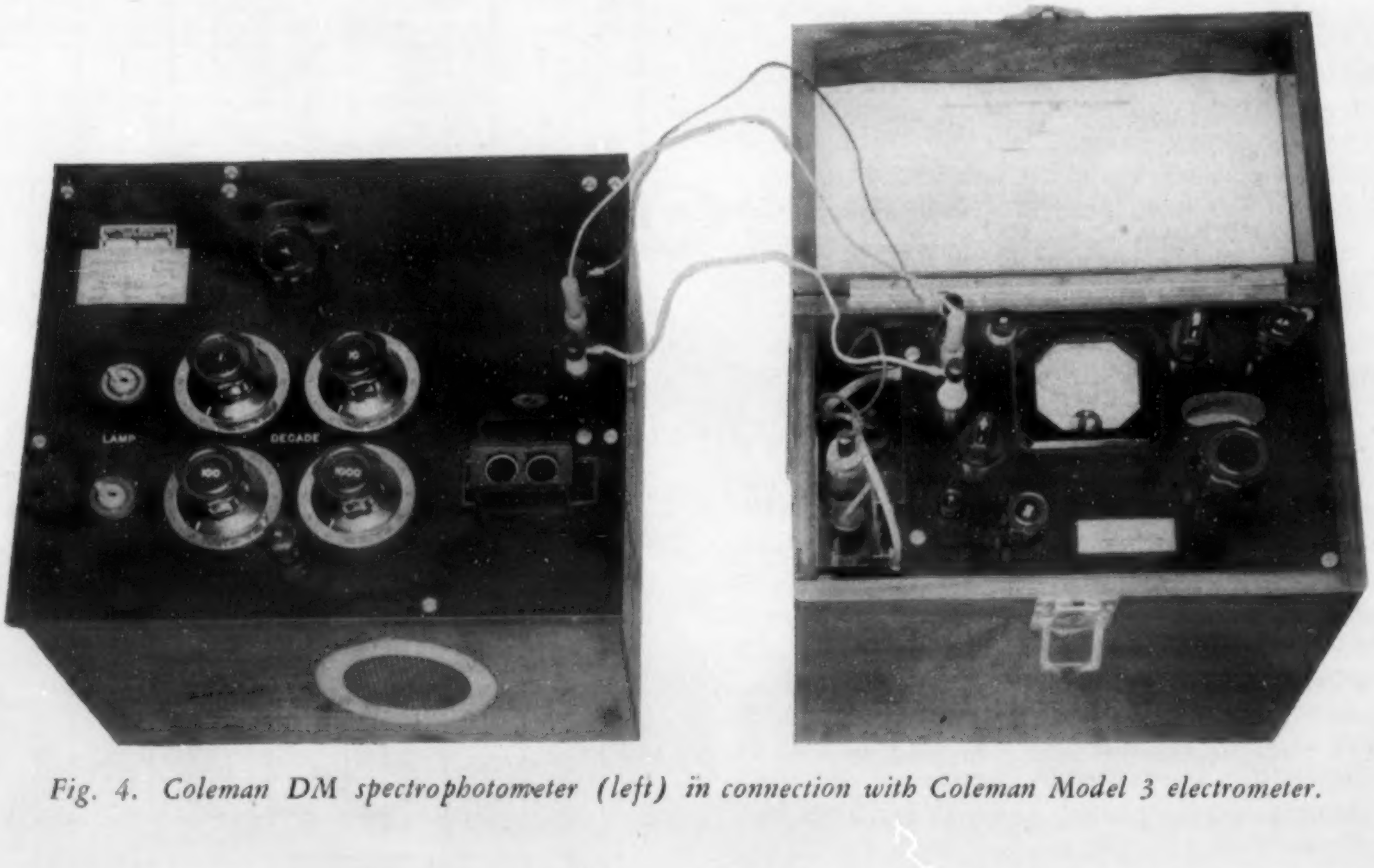


Fig. 4. Coleman DM spectrophotometer (left) in connection with Coleman Model 3 electrometer.

Pouring steel ingots in the open-hearth department. (Courtesy: Bethlehem Steel Co.)

Use of "Chrom-X" in Steel Making

In the July issue of METALS AND ALLOYS, *page 52, there was published an article—"Chrom-X" and Our Chromium Problem. It described the manufacture and use of this new material for adding chromium to alloy steels. An important fact is that it is made from low-grade chromium ores.*

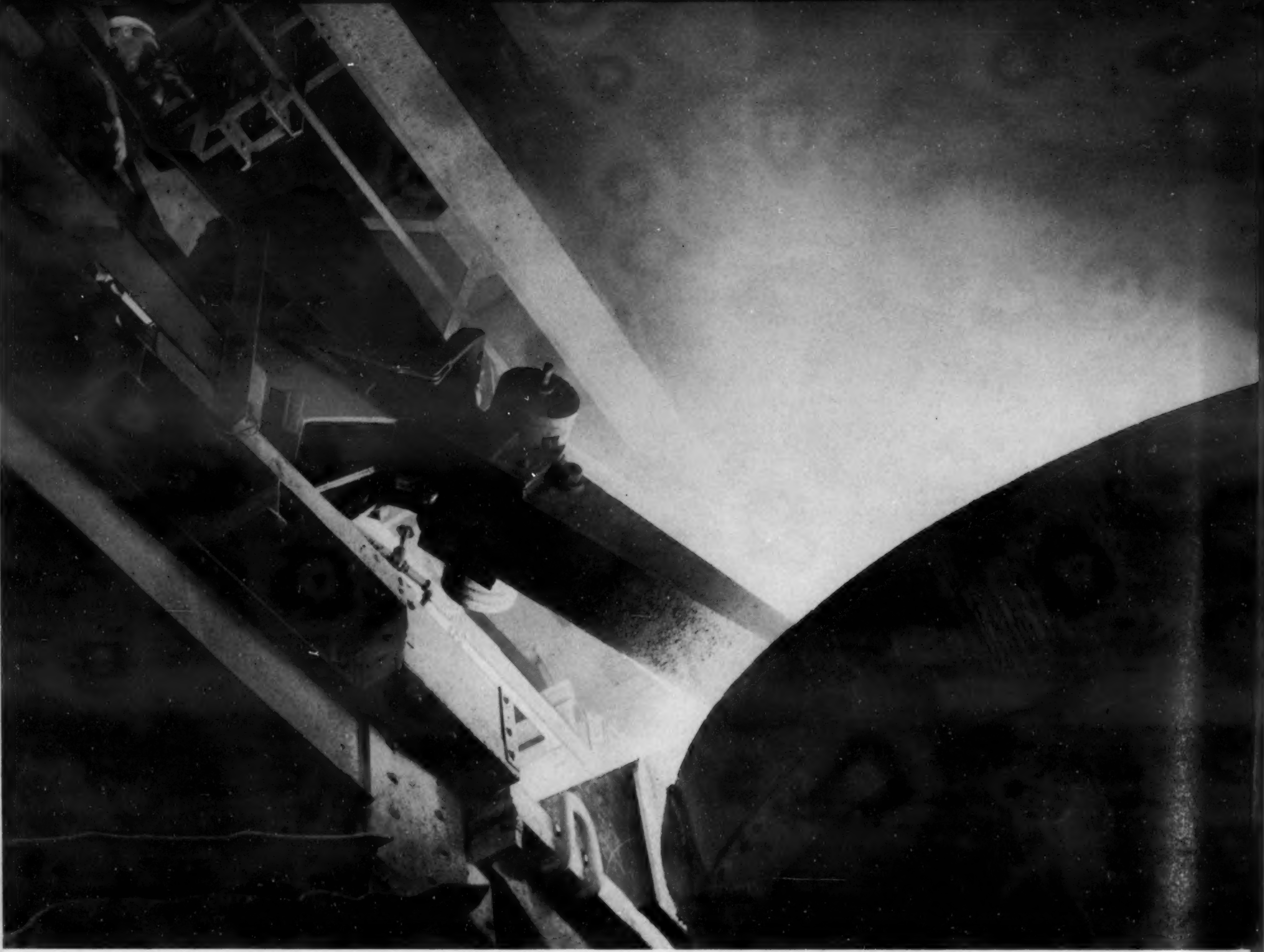
The present article relates the experience of a large steel maker in the application of Chrom-X in producing certain alloy steels of which chromium is an essential constituent. Various phases of the metallurgical operations involved are discussed.

—The Editors.

by JOHN H. McDONALD

Supt. of Open-Hearth Dept., Algoma Steel Corp., Ltd., Sault Ste. Marie, Ontario

EARLY IN 1938 the Algoma Steel Corp. at Sault Ste. Marie, Ontario, was requested by the Chromium Mining and Smelting Corp., who operate a reduction plant in the same city, to make a commercial test on a new material, which had been developed to add chromium to steel. This material, called "Chrom-X," was supplied as a powder packed



Checking the temperature of an open-hearth steel heat during tapping. (Courtesy: Republic Steel Corp.)

in bags or steel drums. It was explained that it was an exothermic mixture which would react, when thrown on a steel bath, to produce molten ferrochromium and a fluid silicate of calcium slag. Ferrochromium, added thus in the molten form, alloys quickly and does not chill the bath to which it is added.

Making a 1 Per Cent Chromium Heat

On March 22, 1938, the first commercial test of Chrom-X was made. The heat was made in a 60-ton basic open-hearth furnace running on producer gas. Specifications for the heat called for 0.30 to 0.35 per cent C and 0.90 to 1.10 per cent Cr. It was run in the usual manner until just after the block with silvery pig. Then the Chrom-X, in paper bags, was charged with charging pans through the center door, followed by an addition of 2000 lbs. of burned lime. Twenty minutes later the heat was tapped.

The Chrom-X used in this test was the low carbon variety, consisting essentially of calcium chromite, calcium chromate, and calcium ferrite with enough silicon added as ferrochromium-silicon to reduce all the chromium and iron to metal. It contained approximately 25 per cent Cr and 14 per cent Fe. The ladle test showed only 0.67 per cent Cr, which was below specifications and represented only 64 per cent recovery of the Cr added.

Making a Chromium Spring Steel

Later a 140,000 lb. spring steel heat with a specification of 0.48 to 0.52 per cent C and 1.00 to 1.20 per cent Cr was made using the same type of Chrom-X packed in steel drums. This was run in the normal manner to the time of blocking with silicon spiegel. Then 2000 lbs. of pebble lime was charged followed by 6800 lbs. of Chrom-X. The reaction was complete in 10 mins. and ferromanganese was added after that.

The heat finished 0.45 per cent C and 1.20 per cent Cr with all other elements within specification. The recovery of the Cr was 85 per cent. All acceptance tests were passed by the steel, and it is even now in service as automobile springs.

In a third test on a 130,000-lb. heat with a specification of 0.35 to 0.38 per cent C and 0.90 to 1.10 per cent Cr the same type of Chrom-X was added as a ladle addition. This heat was run exactly as a carbon steel heat up to the time of tapping except that the slag was thickened with lime near the end to hold back the slag. This latter treatment was later found to be unnecessary.

The Chrom-X was placed in the bottom of the ladle and the steel tapped onto it. The reaction was completed in less than 3 mins. or when the ladle was about two-thirds full, and before the slag started flowing. The ladle analysis showed a chromium content of 1.05 per cent which accounted for 87 per cent of the chromium added. The ladle addition was more efficient and saved more time than the furnace addition.

High Carbon Chrom-X

Early in 1939 we were asked to try another type of Chrom-X. This material had a carbon content which made it equivalent, upon reaction with the molten metal, to the standard high carbon ferrochromium. It is said to be made up of high carbon ferrochromium, (8 per cent or more carbon) ferrochromium-silicon and sodium nitrate. This is all ground fine, intimately mixed, briquetted and packed in paper cartons, with a constant weight of chromium to each carton.

When heated sufficiently, as by contact with molten steel, a vigorous reaction is started, in which the silicon and part of the carbon is burned. Enough heat is produced to reduce the whole mass to molten ferrochromium and molten slag.

Used as a ladle addition the first heat was entirely successful and satisfactory and it has been used ever since for all steels containing up to 1.20 per cent Cr including the S.A.E. chromium, nickel, chromium-molybdenum and chromium-vanadium steels. Practically all of these steels are sold on a grain size and inclusion count specification and results on these specifications as also for tensile and impact tests have been satisfactory. To date 1,250,000 lbs. of the high carbon Chrom-X has been used.

The procedure used with Chrom-X is quite simple and required no drastic change from the practice with ferrochromium. When using ferrochromium, the practice was to bring the carbon down sufficiently below the specification to allow for the carbon in the alloys, take a test for carbometer reading and add silico-manganese to specification. Eight minutes after the manganese addition, ferrochromium was added and held for 22 mins. before tapping. Thus, the heat was tapped 30 mins. after the last carbon test.

Using Chrom-X the heat is brought down in the same manner to a carbon content low enough to allow for alloy additions. After the last carbon test, silico-manganese is added and 12 mins. later the heat is tapped. Chrom-X is added to the ladle and 18 mins. of furnace time is saved.

Recovery of Chromium

The recovery of chromium from ferrochromium averaged 88 per cent while the figure for Chrom-X is 95 per cent. There is more difference, however, than just the 7 per cent increase in recovery. The yield from ferrochromium was very erratic, depending on such factors as size of lumps, temperature of bath and time from addition to tap. The time factor was very important; if too short some undissolved ferrochromium remained in the furnace. If too long, excessive oxidation took place. In fact oxidation takes place while the ferrochromium is melting. Often when the chromium was low because of poor recovery the carbon was also low, indicating incomplete solution. If one heat finished low in chromium the melter was apt to increase the addition on the next heat and like as not end up above the range.

With Chrom-X many of these factors are eliminated. The proper quantity of Chrom-X is thrown into the ladle shortly before tapping and without removing the cartons. There is 25 lbs. of chromium to a carton and a simple way of figuring is to assume 24 lbs. of recoverable chromium to a carton. No weighing is necessary.

The steel is tapped on to the Chrom-X and the reaction starts immediately with a burst of yellow flame (mostly from the cartons) which fills the ladle. Within 1½ mins. the reaction is over and the ladle is about one-third full of steel. The molten ferrochromium is dissolved in the steel and a fluid, quiet slag covers the steel. The stirring action of the falling steel during the remainder of the tap furnishes adequate mixing.

There are factors which may cause a Chrom-X heat to be off composition, of course, such as an error in determining the residual chromium or in estimating the finish weight of a heat. A large majority of the heats, however, finish very close to the desired figure and nearly all are in a range of plus or minus 0.05 per cent. Because the Chrom-X is exothermic and does not take any heat from the steel, the heats need not be as hot and at the same time cold heats are reduced to a minimum.

Use of Chromium Steel Scrap

Chromium steel scrap is used with nearly all heats of chromium steel, and with the last carbon test, residual manganese and chromium are also determined. This gives an opportunity to make a final correction to the ladle addition of chromium. An interesting fact that has been noted is that the residual chromium in the bath often reaches the lowest value about the middle of the heat and then increases toward the end. This reversion from the slag is prob-

TABLE I—Log of Heat No. 1898

Time			
4:40 A.M.	Heat charged		
			Lbs.
	Limestone		14,600
	Hot metal		73,200
	Butts		19,600
	Foreign scrap		29,800
	Iron skulls		5,900
	Pit scrap		7,400
6:05 A.M.	Ore 7000 (59%TE)		4,130
	Total metallic charge		140,030
11:55 A.M.	Spoon test	Cr 0.03%	
12:30 P.M.	Spoon test	Mn 0.32%, P 0.028%, S 0.048%	
1:00 P.M.	Spiegel	500 lbs.	
1:18 P.M.	Silico-manganese	67%—1000 lbs.	
1:18 P.M.	Ferromanganese	80%— 200 lbs.	
1:30 P.M.	Started tap.		
	Ladle additions—	Ferrosilicon—47%	350 lbs.
		Aluminum	20 lbs.
		Coke	100 lbs.
		Titanium	280 lbs.
		Chrom-X	3078 lbs.
1:37 P.M.	Finish tap		
1:43 P.M.	Start pour		
2:15 P.M.	Finish pour		
	Number of ingots	18	
	Mold size	18¾ x 20¾ x 72 in.	
	Finish weight of heat	133,200 lbs.	
	Tapping temperature	3000 deg. F.	
	Pouring temperature	2950 deg. F. 1st ingot	
	Pouring temperature	2900 deg. F. 15th ingot	
	FeO in slag	9.6%	
	Additions at pouring	2½ lbs. Lapix	
	McLean hot tops used		
	Molds, cool, graphite		

ably caused by increased temperature or lower FeO in the slag. In one case that was carefully checked a residual of 0.20 per cent Cr later increased to 0.30 per cent Cr.

Some of the carbon of the Chrom-X is burned in the exothermic reaction and the amount that remains gives a carbon content to the molten ferrochromium of 6 per cent. The simplest way to calculate the carbon pick up in the steel is to allow 0.12 per cent C for each 1 per cent Cr added. It is consistent at this figure for medium carbon steels.

How to Add the Chrom-X

Chrom-X is best placed in the bottom of the ladle just before tapping. If thrown in after the ladle is part full there is apt to be some splashing. If the ladle is too hot or it is left in too long it may react prematurely. In one instance there was a 15-min. delay in the tapping time, and the Chrom-X, already in the ladle, got too hot and was fully reacted before the tap hole was opened. Estimating that the carbon might be low as a result, some extra carbon was added to the ladle. The result was that the carbon was on the high side and a normal recovery of chromium was obtained. The ferrochromium was still hot enough to dissolve readily.

Other ladle additions such as ferromanganese, ferrosilicon and aluminum are held back until just as the exothermic reaction is finished. In this practice normal recoveries of manganese and silicon are obtained as is also a satisfactory control of grain size. The log of a typical heat is shown in Table I.

No Chrom-X heat has been rejected on inclusion count, grain size or for any other reason. In fact it is believed that the Chrom-X heats are cleaner for the following reasons: During the reaction of the Chrom-X the silica produced unites with the soda of the sodium nitrate to form a fluid neutral slag of silicate of soda. This slag covers the steel in the ladle from the time it is a foot deep until the slag from the furnace flows in. The first burst of flame from the Chrom-X sweeps all the air from the ladle. That helps prevent re-oxidation of the steel but the slag covering is even more effective in this regard. During the filling of the ladle there is no splashing or sparking of the steel such as occurs on a bare surface.

Besides excluding the steel from contact with the air, this slag has a washing action on the steel as it rolls over and over during the tap. Another effect is to conserve aluminum, which, when added to the ladle, floats on the surface and ordinarily burns in the air while dissolving in the steel. The silicate of soda slag covers the aluminum, prevents air oxidation and makes grain size control easier and more consistent. Although this acid slag is a product of the Chrom-X, its effect is incidental to the use of this material, and it would seem in order, to consider the use of some such slag on all heats whether alloy steels or not.

Fluid Acid Slags and Clean Steel

The idea that a fluid, acid slag is of value in promoting cleanliness in steel is not new. Agaletski[1, 2, 3] described experiments done at the Russian Institute of Metals, in which basic open-hearth steel was poured through synthetic, acid, deoxidizing slags such as those recommended by Perrin.[4] This treatment was claimed definitely to improve the inclusion count of the steel mainly in respect to the larger inclusions.

Chrom-X needs more care in storage than ferrochromium. It must be kept dry and placed where it will not come in contact with hot metal or slag. The advantages that have been found for it include a saving in furnace time, higher recovery of chromium, and minimum of cold heats. More consistent recovery of both chromium and carbon means fewer heats outside of specifications. The protective slag formed, promotes cleanliness, minimizes loss of deoxidizers and makes grain size control easier.

Making High Alloy Steels With Chrom-X

The Algoma Steel Corp. does not regularly make any high alloys steels, but did make, on a purely experimental basis, four heats of 4 to 6 per cent Cr and two heats of 11 per cent Cr steels, using low-carbon Chrom-X as the source of chromium.

These were made in a 60-ton basic open-hearth furnace but were charged short (about 50 tons) to allow for the extra large slag volume. The Chrom-X was charged to the furnace by machine after the heat had been boiled down in regular manner to 0.08 per cent C. Because these are stationary furnaces the melt down slag could not be removed, and because the iron oxide was reduced from this slag there was some reversion of phosphorus. To keep the phosphorus down in the steel it was found necessary to charge low phosphorus scrap and a small amount of low phosphorus pig which was bolstered with 2½ per cent of coke to maintain the proper carbon at the melt down.

In the first heat the reaction of the Chrom-X did not produce enough heat and was very sluggish. In the second trial there was too much heat and the flame had to be shut off and the doors of the furnace opened to prevent damage to the refractories. In all subsequent heats it has reacted quickly and quietly without producing any appreciable change in the temperature. During one 11 per cent Cr heat 60,000 lbs. of Chrom-X was added and the reaction was completed in less than one hour.

Open-hearth practice for such steels was by no means standardized but an example of one 4 to 6 per cent Cr heat will exemplify the practice used and the results that can be obtained. The log of such a 50-ton chromium-molybdenum heat is given in Table II. In this heat, calcium molybdate was added after the melt down and then the heat was boiled down to 0.09 per cent C.

At this time 2000 lbs. of pebble size ferrosilicon was added to partially clear the refining slag of iron oxide. Then 28,600 lbs. of Chrom-X, in paper bags, was added in 9 mins. and the reaction was complete 4 mins. later. The bath was rabbled before a sample was taken. The bath at this stage was perfectly quiet.

Then 2000 lbs. of 3-in. air dried limestone was added to create a gentle boil by the liberation of the carbon dioxide. This was done because some unreacted silicon is carried down into the metal while some chromic oxide is left in the slag. The lime boil has been found to speed the reaction of these two materials providing there is not enough added to chill the slag.

Spoon samples were poured into small dry sand molds where they cooled without chilling. Under these conditions the silicon content can roughly be estimated. With high silicon the surface freezes smooth while a characteristic roughening or wrinkling begins when the silicon gets below about 0.20%.

It will be noted that, although this experimental heat was held in the furnace for 1½ hrs. after the Chrom-X was added, it was ready to be tapped ½ hr. after the addition. The desired composition and the actual analysis of the ladle test are given below:

	C	Mn	P	S	Si	Cr	Mo	Ni
Ordered	0.15 max.	0.20 to 0.50	0.03 max.	0.03 max.	0.20 to 0.50	5.00 to 6.00	0.45 to 0.65	0.50 max.
Actual	0.11	0.36	0.038	0.025	0.32	5.03	0.57	0.17

TABLE II—Log of Heat No. 3129

11:25 A.M.—Began charging
11:45 A.M.—Finished charging
6:30 P.M.—First preliminary
Mn 0.15, P 0.020, S 0.038, Cr 0.01, Ni 0.08, Mo 0.02%
6:30 P.M.—470 lbs. molydenum as calcium molybdate
7:30 P.M.—50 lbs. molybdenum
7:50 P.M.—Heat melted
7:52 P.M.—Second preliminary—C 0.50, Mn 0.10%
8:05 P.M.—Third preliminary—C 0.36%
8:15 P.M.—700 lbs. ore
8:23 P.M.—Fourth preliminary—C 0.22%
8:30 P.M.—200 lbs. ferromanganese
8:40 P.M.—Fifth preliminary—C 0.15%
8:50 P.M.—Sixth preliminary—C 0.13%
9:00 P.M.—Slag and metal test
Metal—C 0.10, Mn 0.19, P 0.004, S 0.021, Mo 0.64
Slag—FeO 20.88, Fe_2O_3 11.52; MnO 6.83, SiO_2 9.68, CaO 41.44, MgO 7.20, P_2O_5 0.574, Al_2O_3 0.97, Cr_2O_3 0.49, Total S 0.267%
9:00 P.M.—2000 lbs.—50% ferrosilicon
9:05 P.M.—28600 lbs. Chrom-X addition started
9:14 P.M.—Chrom-X—all in furnace
9:18 P.M.—Reaction finished
9:20 P.M.—Heat rabbled
9:23 P.M.—First sand mold test—C 0.10, Mn 0.32, P 0.024, Si 0.74, Cr 6.82%
9:24 P.M.—2000 lbs. limestone
9:40 P.M.—Second sand test—C 0.11, Mn 0.32, P 0.034, Si 0.33, Cr 5.58%
9:49 P.M.—Third sand test—C 0.11, Mn 0.32, P 0.032, Si 0.31, Cr 5.18%
Heat was rabbled frequently during this period
9:59 P.M.—Fourth sand test— C 0.10, Mn 0.32, P 0.033, Si 0.32, Cr 5.02%
10:09 P.M.—Fifth sand test—C 0.09, Mn 0.33, P 0.034, Si 0.20, Cr 5.02%
10:13 P.M.—6 shovels of limestone
10:19 P.M.—Sixth sand test—C 0.09, Mn 0.32, P 0.037, Si 0.21, Cr 5.02%
10:25 P.M.—1 bag coke
10:32 P.M.—Seventh sand test—C 0.09, Mn 0.32, P 0.036, Si 0.20, Cr 4.94%
10:33 P.M.—Slag and metal test
Metal—C 0.11, Mn 0.36, P 0.038, S 0.025, Si 0.22, Cr 5.04, Mo 0.54%
Slag—FeO 3.60, Fe_2O_3 0.48, MnO 2.96, SiO_2 31.66, CaO 43.23, MgO 9.60, P_2O_5 0.258, Al_2O_3 1.26, Cr_2O_3 5.34, Total S 0.195%
10:35 P.M.—Tapped
10:45 P.M.—Finished tapping
Temperature: Steel pour—2980 deg. F.
Finish pour—2960 deg. F.

The above are optical temperatures. They are without doubt inaccurate due to irregularities of emissivity corrections on high chromium steels.

Nozzle size—1½ in.

All molds were hot topped and tarred.

The phosphorus was slightly high because of contamination from the hearth. The chromium was on the low side of the desired range and represents only 80 per cent recovery of the chromium added. This recovery could undoubtedly be improved substantially if the refining slag could be removed before the Chrom-X is added.

Billets from this heat were rolled and tested in a plant having wide experience with this composition. The steel passed all regular physical, etch and cleanliness tests. Some of it was pierced for tubing.

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[3] F. Agaletski. "Treatment of Basic Open Hearth Steel with Synthetic Acid Slag to Make It Non-Aging," *Stal*, Vol. 7, No. 10, 1937, pages 15-19.

[4] R. Perrin. *Rev. mét.*, Vol. 30, 1933, pages 1-10, 71-84.

Electric Salt Bath Treatment of Al

"How to do it faster and still do it better" is the special quest of metallurgical engineers working with all types of products today. For the solution treatment prior to aging of aluminum alloy aircraft parts, Brewster Aeronautical believes it has the answer in electric salt bath treatment, described in this article.
—The Editors.

by C. Santore

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THE ADVANTAGES OF SALT-BATHS for the "solution heat treatment" of aluminum alloy aircraft components have long been evident. Salt baths not only provide protection against oxidation, but give somewhat more assurance of uniform heating than do air furnaces, and the rate of heat transfer is much faster from molten salt than from heated air, even when the latter is well circulated. The practical result is that solution-treatments in a liquid salt bath can be much shorter than in other types of furnaces. Of course, these statements are not necessarily true for other aluminum alloy treatments, such as full annealing or artificial aging.

The importance of this factor of speed of production is obvious today. Our selection of an *electric* salt-bath furnace for this application, in addition, was based on the accuracy and uniformity of bath temperature, the cleanliness of operation and the satisfactory overall economy provided thereby. For our work we now use three Ajax-Hultgren immersed-electrode furnaces—one large unit for solution-heat-treating 24ST and 24SO (both nominally 4.2 Cu, 1.5 Mg, 0.5 per cent Mn, remainder Al) extruded sections, sheet and formed parts, and two smaller units for 17S alloy rivets (4.0 Cu, 0.5 Mg, 0.5 per cent Mn, remainder Al). Most of these are components for Brewster-fabricated sections of Consolidated PBY-2 patrol bomber flying boats—outer wing panels, retractable wing-tip floats, brace struts, etc.

Heating Large Parts

The large furnace is a 60-kw. unit and has a pot 10 ft. long by 32 in. wide by 40 in. deep. Three pairs of electrodes are employed, the current passing from one electrode to its twin through the molten salt between which is thus heated and kept in rapid circulation [as described in articles in METALS AND ALLOYS, June 1936 and August 1938]. The salt used is a half-and-half mixture of sodium and potassium nitrates, and fills the pot to within 4 in. of the top.

A large part of the production of this large furnace consists of 24SO parts, such as keel angles for pontoon boats (nearly 10 ft. long), wing-rib contours, stringers, etc. These are formed from annealed sheet or strip, and when formed are treated in the salt-bath furnace at 925 deg. F. for specified time periods, which vary with the thickness of the part.

Treatment times are 30 min. for 1/16 to 1/8 in. sections; 45 min. for 1/8 to 1/4 in.; and 1 hr. for 1/4 to 1/2 in. At completion of the heat treatment the parts are removed from the bath and immediately quenched in cold water in a large tank; if no more forming is required, they are allowed to age at room temperature for 48 hrs., and then transferred to the finishing and assembly departments.

However, some small parts must undergo still further cold working (here the solution treatment serves the purpose of a process-anneal) and these parts are immediately transferred to the forming machine and formed within 30 min., or before spontaneous aging lowers the ductility. If for some reason forming cannot be completed at once, the parts are placed in a refrigerator at a maximum of 18 deg. F. to arrest age-hardening, and kept there until the shop is ready for them. Parts can be reheat treated as many times as desired as an aid to forming. Reheat treatment is for half the time of the original, at the same temperature.

In addition to the annealed-and-formed parts treated in this large furnace, certain 24ST (age-hardened at the mill) components are heat treated in the salt bath before forming. For example, the top deck of the PBY retractable wing-tip-float is a hydraulic-press-formed stamping 10 ft. long and 3.5 ft. wide—probably one of the largest stampings pressed hydraulically in the industry. To make this, 24ST sheet is first heated in the salt-bath at 925 deg. F. (or half the time required for a 24SO part of the same thickness, since this is actually a reheat treatment for 24ST). The sheet is quenched and is then immediately roll-flattened and formed in a hydraulic press while still in the solution-annealed or soft condition, after which it is allowed to age-harden at room temperature.

# of Aluminum Aircraft Alloys

Heat Treating Rivets

The two small furnaces, used for rivet-treating, are each 15 kw. units, with pot dimensions 3 ft. by 6 in. by 12 in., each heated by one pair of electrodes. The rivets are of 17SO alloy, previously anodized, and are heated at 930 to 950 deg. F., quenched to the soft, solution-annealed condition, and transferred immediately to the refrigerator to arrest aging until the assembly department is ready to use them. The rivets are subsequently driven soft and allowed to age in place; for correct driving-temper the rivets must be driven within 30 min. after removal from the refrigerator.

During heating in the salt bath the rivets are protected from direct contact with the molten salt (which would introduce subsequently difficult cleaning or corrosion problems) by placing them in perforated closed-bottom tubes, which are themselves set inside vertical stainless steel tubes also closed at the bottom; thus, only the outside of the "stainless" tubes is in contact with the salt. The rivets are "poured" into the inside tubes through funnels, and each tube can hold ½ lb. of rivets. The tubes can be so nested in the furnace that 16 lbs. of rivets can be treated at one time. Ordinarily, the production rate in each furnace averages 27 lbs. of rivets per hour.

The time-periods given above for parts apply also to rivets. Most rivets are 1/16 to 3/16 in. thick, hence are heated for 40 min. when in the annealed condition. However, treated rivets are not always used by the assembly department soon after being placed in the refrigerator, and such rivets that have been in the refrigerator more than 48 hrs. are removed and reheat treated—same time and temperature as the original treating period to insure ductility for driving. Rivets may be refrigerated and reheat treated in this manner 15 times before use, if necessary.

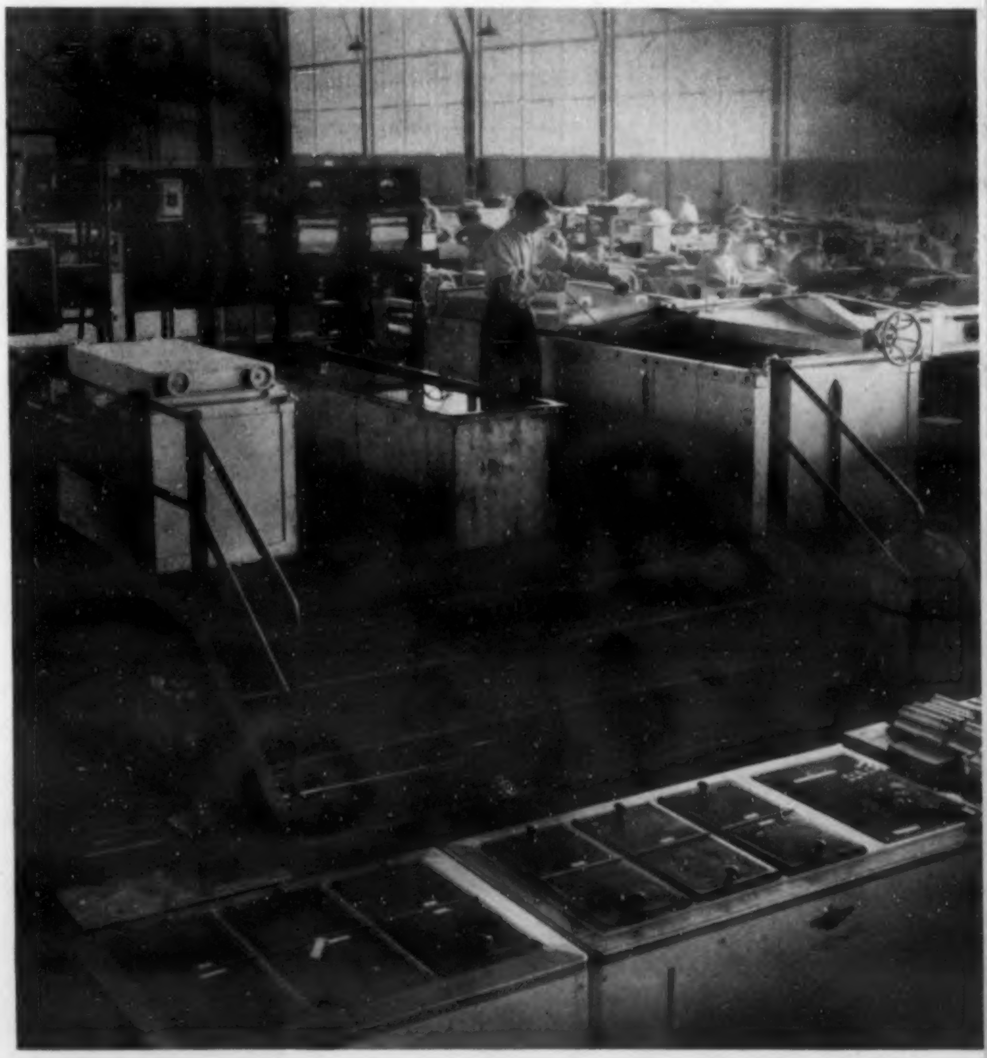
Other Features

The performance of these furnaces has been satisfactory in every respect, as has been that of three furnaces of this type doing similar work at Brewster's Long Island City plant. Pots are made of ordinary mild steel plate, and after more than a year of steady operation, no replacement of pots (nor of electrodes) has been necessary.

The precision of temperature control seems to be ideal. For example, the specifications for rivet heating call for temperatures of 940 deg. F. plus or minus 10 deg. F., yet in these furnaces the temperature at different moments and at various points within the bath has always checked within 5 deg. F. Salt consumption runs about 500 lbs. every three weeks.

One outstandingly convenient feature of these particular furnaces, manufactured by Ajax Electric Co., Inc., Philadelphia, is the mechanically-operated rolling-type cover on each of them.

The original installation (2 furnaces) of internally-heated electric salt-bath furnaces for the solution heat treatment of duralumin-type alloys at the Brewster plant. The operator is working at the long furnace for parts, with a rivet furnace at the left. In the foreground can be seen the refrigerators for arresting aging.



Brake Drums—I

By OLIVER SMALLEY

President, Meehanite Metal Corp., Pittsburgh

Though this article deals only with brake drums, considerable light is thrown on the general subject of heat checking which can appear on a variety of metals in a variety of uses. Many of Mr. Smalley's thoughts will carry over to other troublesome practical problems.—H. W. G.

BASICALLY A BRAKE DRUM is part of a mechanism that converts energy of motion into heat. The amount of heat generated and the speed of dissipation of this heat are, therefore, the main factors that determine the life of any brake drum. They are factors which, theoretically, appear simple of analysis and calculation, yet practically are bewildering in their complexities.

The three major requirements that must be considered in the selection of a material for brake drum manufacture are initial cost, performance, and service life.

Initial cost must have direct relation with the expected overall service life. It is for this reason that materials such as steel, both low and high carbon; combinations of light alloys or steel backed with a cast iron ring, and all cast iron drums have found general favor, for while they present certain shortcomings their low initial cost presents obvious advantages.

Performance covers design, heat dissipation, coefficient of friction, type of wear surface developed, and general maintenance of drum form during its operating life. In service a brake drum has to take care of the bulk of the energy converted into heat through conduction, convection, and radiation regardless of design. With the high speeds and quicker stops of the modern vehicle in service under varying conditions of weather, this is presenting an ever increasing problem to both the metallurgist and the engineer. Unfortunately, theoretical formulas for calculation of heat flow and temperature, while possible for laboratory tests, are most difficult to interpret to road service.

We do know that the wear of a brake drum is not necessarily simple mechanical disintegration, for electron-defraction studies reveal that there may be an actual fusion of the brake drum surface. This is far reaching in its implications, for while many students of brake drums like to report on brake drum temperatures as approximately 400 and sometimes reaching 1200 deg. F., actually the contacting surface is always considerably higher and more often than not the immediate backing layer will exceed the higher figure.

Any laboratory study of the physical properties of a brake drum material at ordinary temperature conditions, therefore, has little meaning so far as wear is concerned and is unlikely to be of any help except under conditions where braking is of the mildest type. Immersion pyrometer tests are of themselves also misleading, for any examination of the surface of a brake drum after ordinary service will show structural changes that could only have taken place at much higher temperatures than those recorded.

It is unfortunate, in these days of scientific enlightenment, that we should know not only so little about such questions as to what "wear" actually is, but that the modern metallurgist should possess so little fundamental knowledge on the behavior of common cast iron and steel at elevated temperatures and, for that matter, on the physicochemical properties of cast iron and steel at temperatures likely to be encountered in brake drum service.

We do know in a general way that the co-efficient of thermal conductivity of both cast iron and steel falls rapidly with an increase in temperature, but exact figures for the various kinds of common steels and cast iron are not available. We satisfy ourselves by saying that steel has approximately 22 per cent greater conductivity than cast iron, but as almost every grade of cast iron has a different thermal conductivity this does not mean too much.

We have in a general way also some knowledge of the specific heat of both steel and cast iron at elevated temperatures, but even this simple property has not been established positively.

We know something of the creep strength of certain cast irons and mild steel at the lower temperatures, yet we know nothing of their fatigue or endurance properties at elevated temperatures or the effect of varying conditions of temperature change. After all, the stress encountered in a brake drum is not only a complex dynamic stress at elevated temperatures, but is one of rapidly changing intensity accompanied by drastic temperature changes. Much has been done to attempt to correlate Brinell hardness of a brake drum with its service life and wear resisting properties, yet we have little or no knowledge of how the Brinell hardness varies under temperature influence or what the Brinell hardness of the actual wearing surface of the brake drum is likely to be in service.

Some idea of what is involved in this regard is shown by the following tests in the Table, made on certain brake drum irons at room temperature and at 1200 deg. F.

Table of Effect of Temperature on Brinell Hardness Numbers of Various Brake Drum Cast Irons

Composition								B.H.N.		
T.C.	Si	Mn	S	P	Ni	Cr	Mo	At 70°	At 1200°	Cold after heating to 1200°
3.26	1.64	0.73	0.111	0.102				217	107	207
3.40	1.77	0.73	0.072	0.112				217	123	223
3.26	1.92	0.86	0.098	0.108	1.31	0.25		248	121	241
3.48	1.89	0.94	0.140	0.107			0.75	235	152	235

These figures were obtained on each specimen after holding at the temperature indicated for 1 hr. Just what the readings would indicate after several heatings and also after long periods of heating is not shown, but the above tests do show clearly that consideration of Brinell hardness at room temperature is one thing and that at the temperature of the drum in service is another.

Structure, Properties and Service

Many studies have been made by various authorities of brake drum materials attempting to prove that this or that microstructure is essential for long service life. A too commonly made statement is that a *"pearlitic structure"* is essential to good wear and to avoid scoring of cast iron brake drums. This, unfortunately, is also another somewhat meaningless expression for pearlite itself is not a simple structure and the matrix of almost any cast iron poured into light brake drums is mostly pearlitic in one form or another, yet I am sure we are all agreed that just any sort of cast iron is not the right material for all brake drums. Figs. 1 and 2 reveal the structure of two brake drum irons exhibiting so-called pearlitic structure.

The nickel people instruct us that high test irons with a tensile strength of 40,000 to 50,000 lbs per sq. in. should be used on brake drums where it is

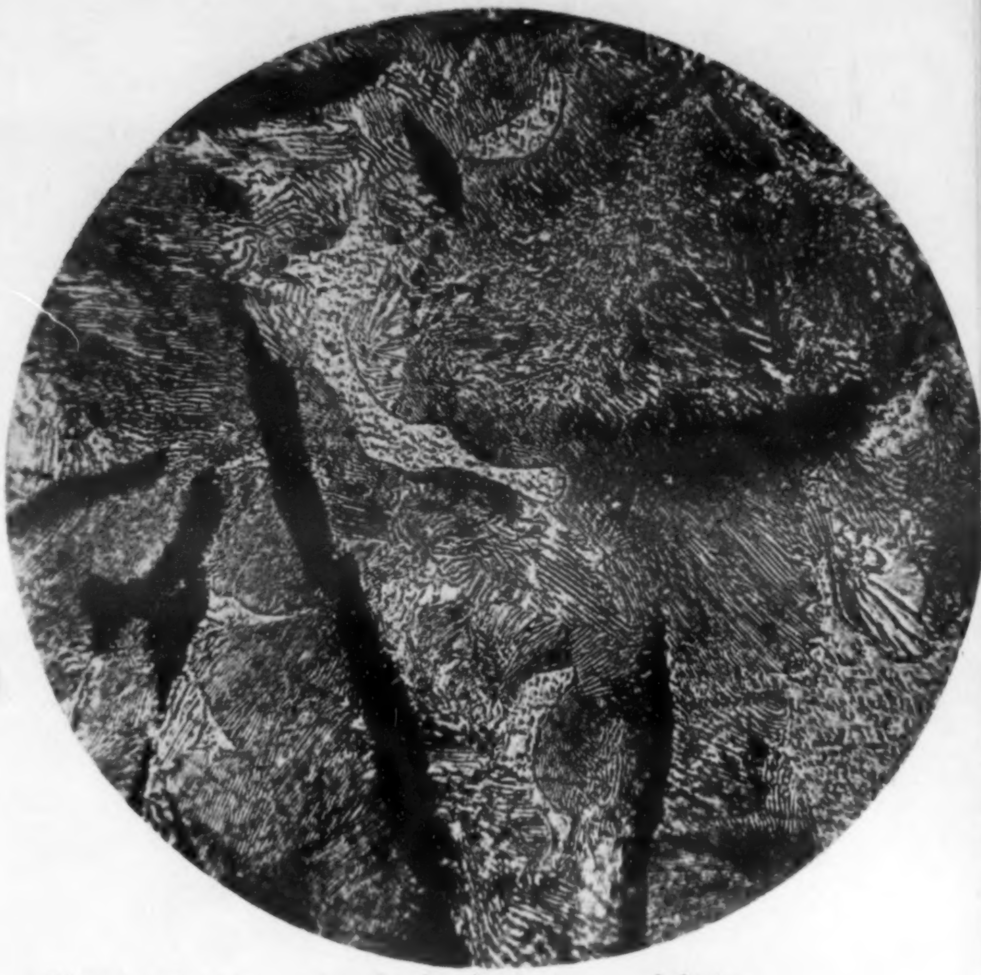
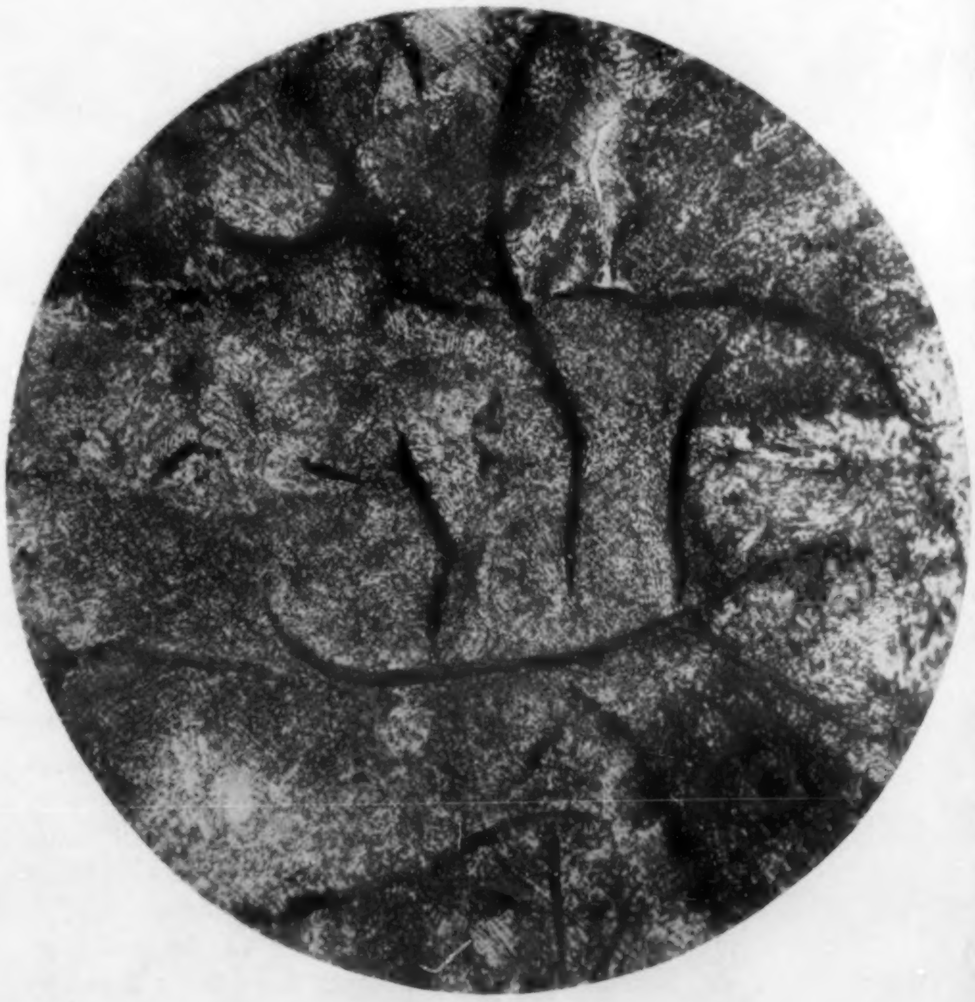
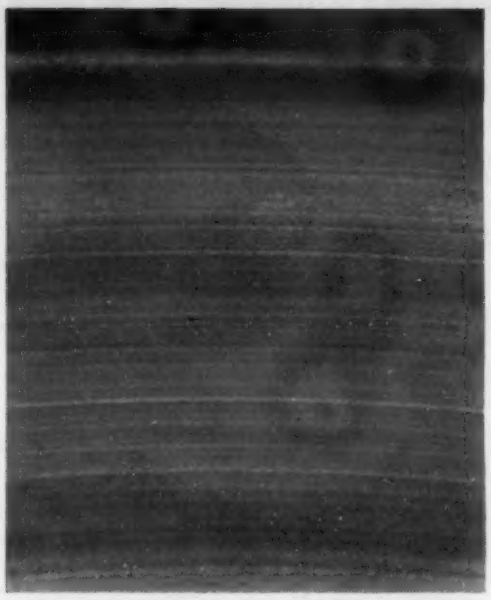
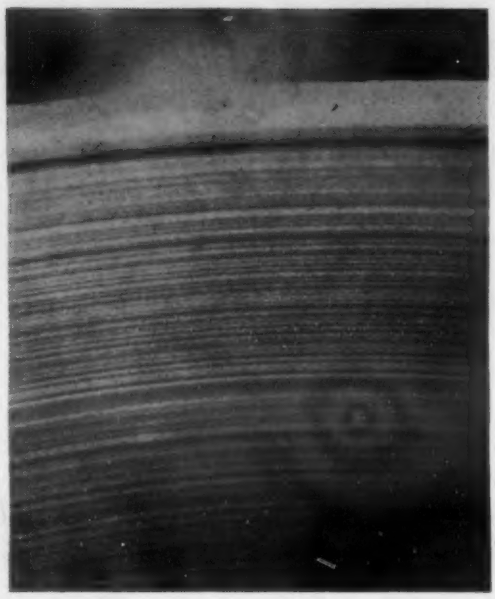


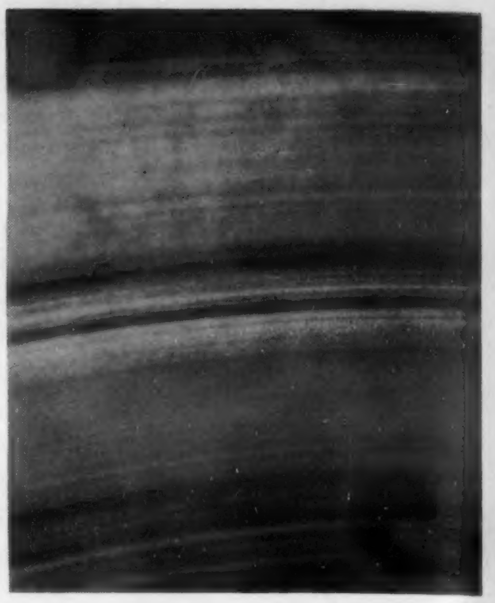
Fig. 1. Structure of a brake drum iron exhibiting pearlitic structure. Tensile, 31,020 lbs. Brinell—187. Reduced 1/3 from an original of 1000 dia.

Fig. 2. Another structure similar to Fig. 1. Tensile, 42,000 lbs. Brinell—237. Reduced 1/3 from an original of 1000 dia.









Figs. 3, 4 and 5. Typical examples of scoring in city bus drums involving frequent high-speed stops.

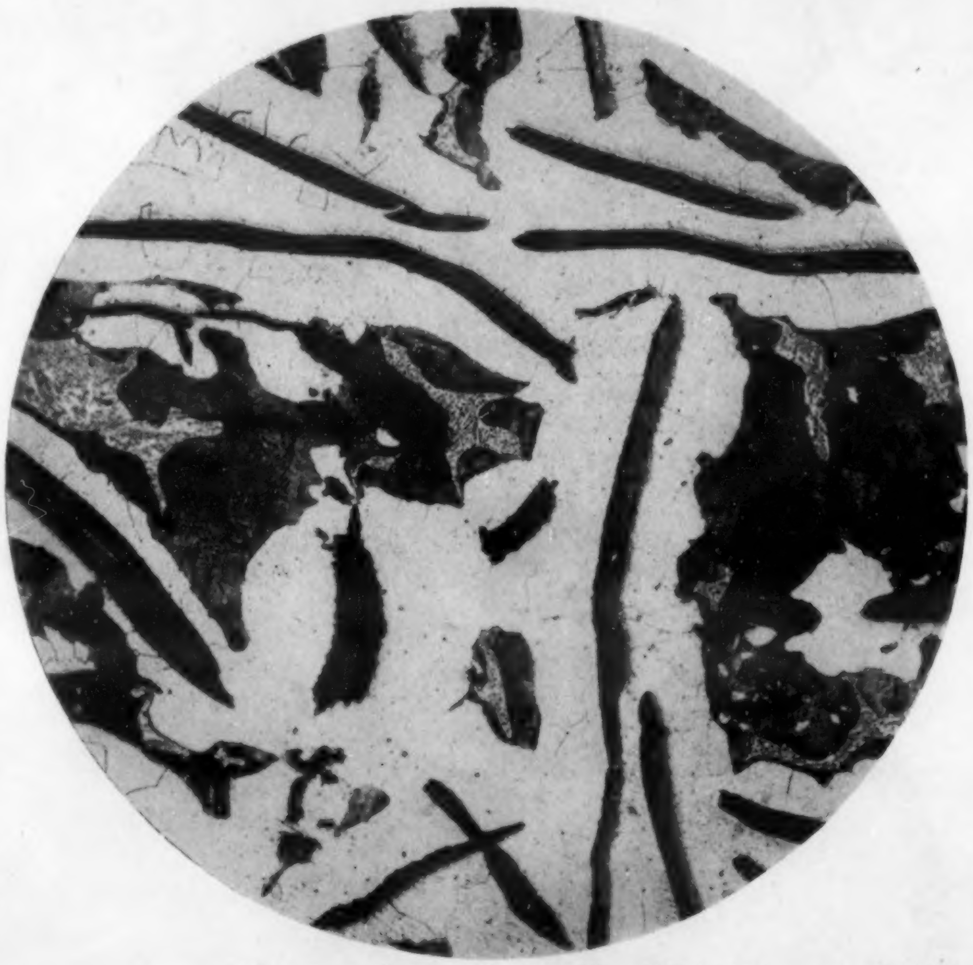


Fig. 6. A ferritic iron. Reduced 1/3 from an original of 1000 dia.

desirable to save weight. Such statements again are meaningless, for it is questionable whether tensile of itself conveys anything on the performance of a brake drum. Actually, our knowledge of both the metallurgy and mechanical properties of brake drum materials is, at the best, both superficial and scanty.

Returning to the main problem of the brake drum which is converting work into heat, we do know that in the severe service of the modern drum, heat is often generated much faster than it can be dissipated and also that this may happen more times than the drum can withstand without developing serious and objectionable defects. For the most part these defects usually take the form of scores and thermal cracks.

Scoring

On first consideration the cause of scoring in brake drums appears obvious. A particle of sand or foreign material finds its way in the brake mechanism, and locating on the surface of the brake lining is all that is needed to start a cutting action under the pressure of braking. Each of the small particles of metal so removed will also become imbedded in the brake lining and act individually as cutting tools by removing more and more from the surface of the brake drum—a process which is cumulative until the drum is badly worn and the lining cut up and loaded with metal.

The three examples (Fig. 3, 4 and 5) are typical of this kind of scoring in city bus drums involving high speed stops at frequent intervals. This, unquestionably, is one cause of scoring, but both the brake mechanism, the material from which the drum is made and the condition of the drum may have quite an important influence on scoring.

Drum distortion causing extremely high pressures over localized areas is a common cause of scoring. A too abrasive type of brake lining, or a lining that is harder than the drum, or a lining that wears in powdery form, or other conditions of the lining that cause cutting of the drum surface will result in scoring.

The remedy for this is obvious, and first consideration should be given to proper selection of lining to drum material or drum material to lining, but in either case the nature of the service and the design

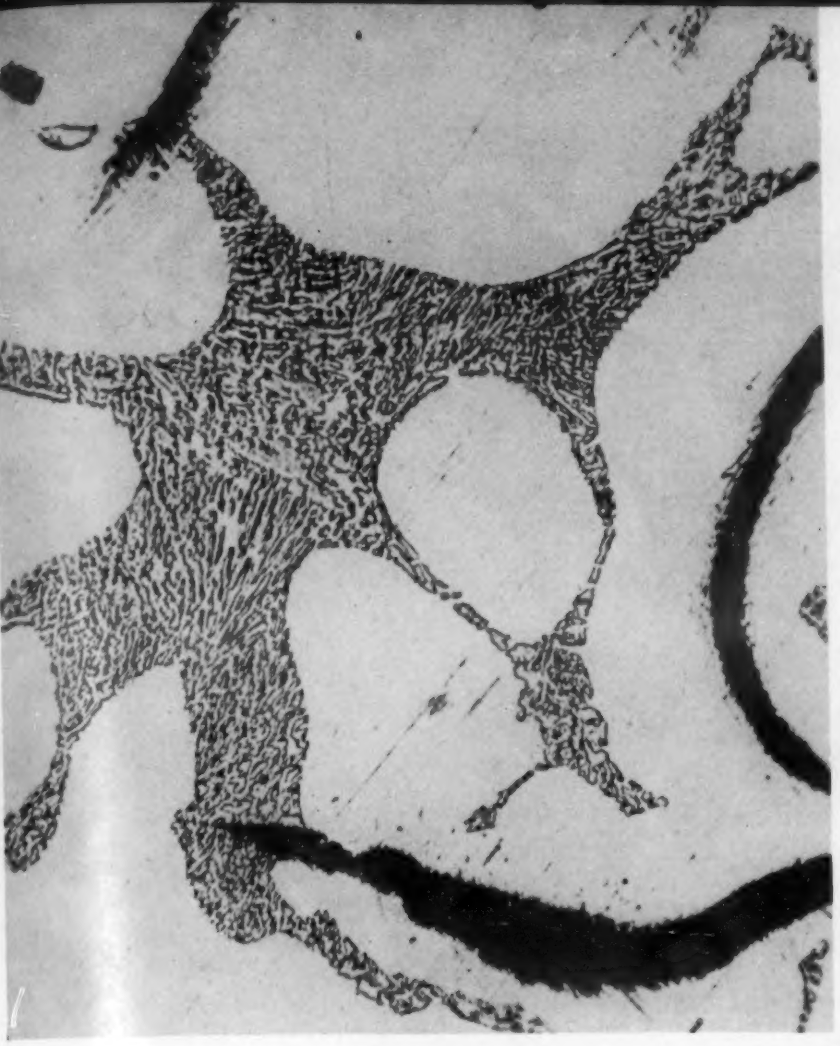
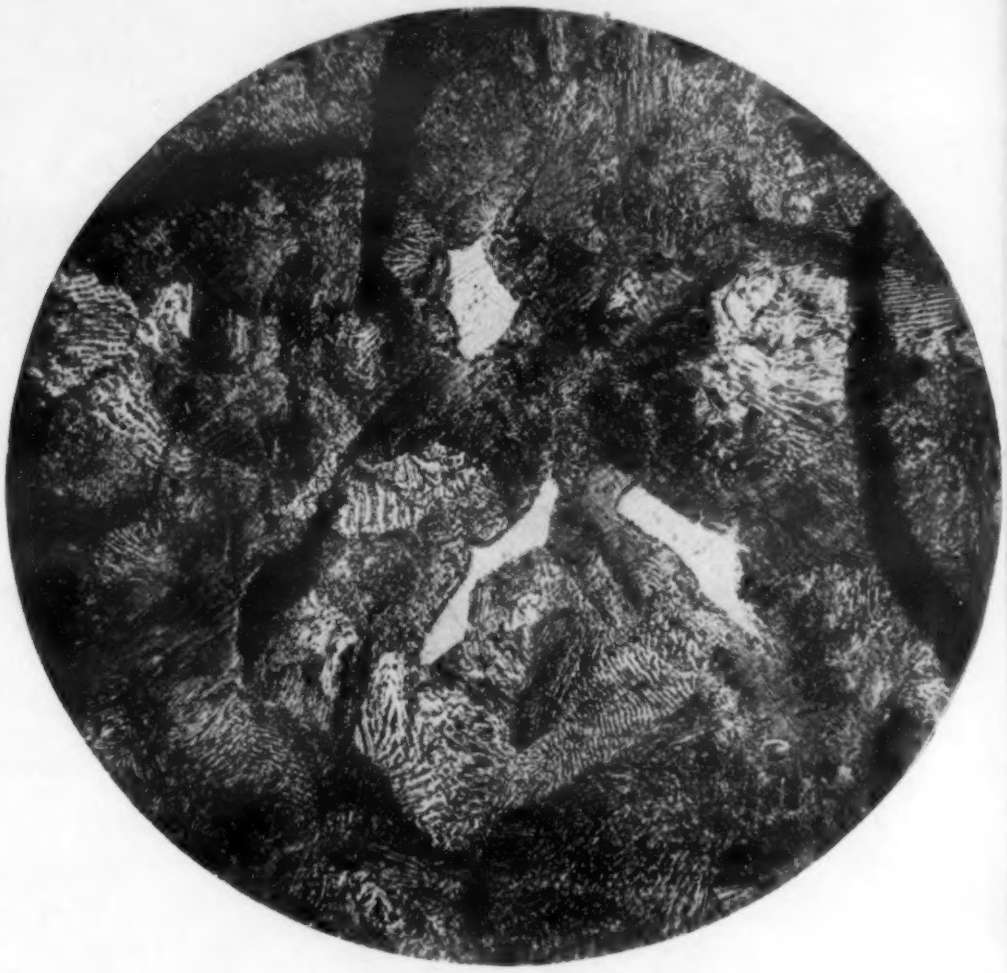


Fig. 7. (Left) Brake drum iron showing free phosphide network. Reduced 1/3 from an original of 1000 dia.

Fig. 8. Cementite in a brake drum iron. Reduced 1/3 from an original of 1000 dia.



of the drum are also factors which cannot be ignored. Dragging brakes, failure to release brake pressure immediately after the stop is completed, and unnecessary abrupt stops are important contributing factors.

A common cause of scoring is over-heating, but a drum scored because of over-heating does not necessarily display thermal checks for the surface may wear away almost as fast as the checks are formed, and often only a close examination will reveal minute thermal cracks.

Selection of the Iron

The remedy of scoring through over-heating may lay in the selection of an iron with larger quantities and a better distribution of graphite in a harder matrix or in the use of a softer lining or a better design of brake mechanism. Scoring in waves or grooves is often an indication of free patches of ferrite in the microstructure of the drum. (See Fig. 6.) The presence of this constituent always tends to reduce wear, cause pick-up and galling, and end in uneven wear.

The use of phosphoric irons, that is, irons containing over 0.4 per cent P, are thought to favor scoring on account of the tendency of the particles of the hard friable phosphide to fall loose from the base metal and become imbedded in the lining; however, the presence of phosphorus under certain conditions does improve the wear resisting qualities and, providing the phosphide can be obtained in minute enough form particularly in the centrifuse type of drum, it is believed that it may have certain advantages. (See Fig. 7.)

Effect of Free Cementite and Slag

In a relatively coarse form the presence of this constituent is considered undesirable. Hard spots result on machining and scoring difficulties follow. The presence of cementite also causes rapid and uneven wear of the lining since the softer pearlite matrix wears away, leaving the hard cementite in relief to act as a cutting tool. (See Fig. 8.)

Cleanness of iron—freedom from slag particles, mostly sulphide of manganese—is quite a factor in the life of a brake drum, particularly in resisting scoring. Slag inclusions in brake drums have not received the consideration that they deserve. Photomicrograph, Fig. 9, shows a polished sample of such a drum, magnified at 100 times. Photomicrograph, Fig. 10, shows the same drum, after polishing and etching, magnified 500 times. This particular drum was used on heavy service city buses subject to frequent stops.

The black streaks in both photomicrographs are flakes of graphite which is of good form. The small round gray colored particles distributed throughout

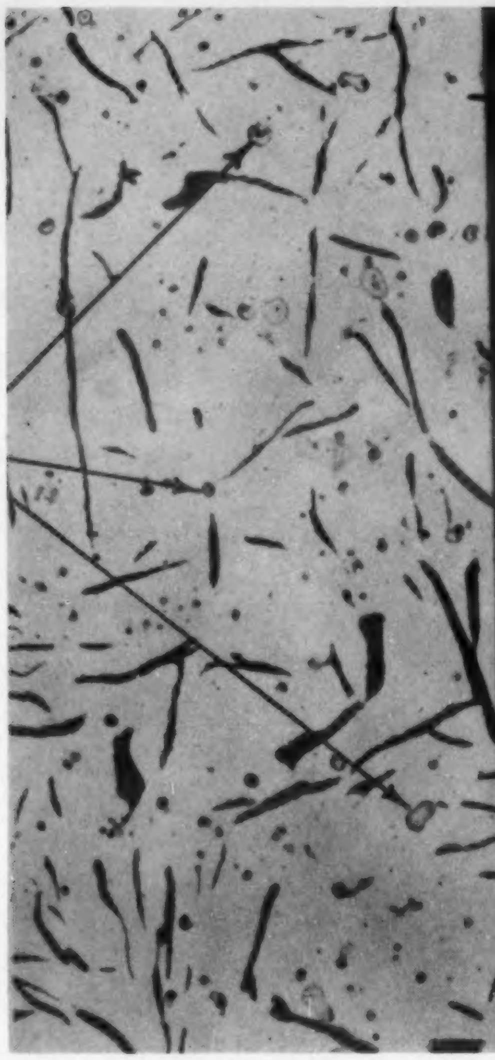


Fig. 9. Polished sample of a drum iron showing slag. 100X.

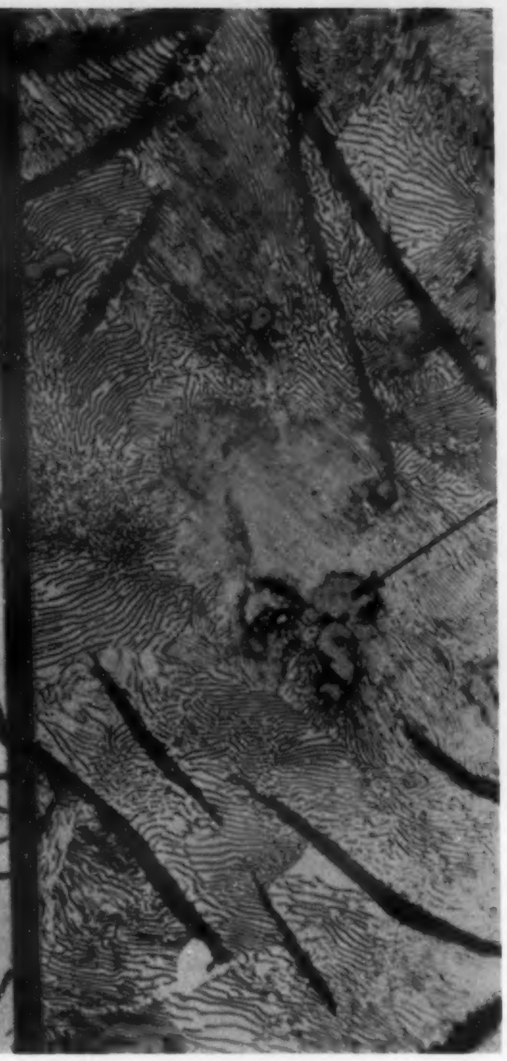


Fig. 10. Same iron as Fig. 9 after etching. 500X.

the whole matrix in Fig. 9 and one bunch of them at a higher magnification in Fig. 10 are slag particles.

This brittle, slaggy material is common to iron that is poorly melted or to a drum that is cast without due consideration being given to proper methods of molding and to the gating system in the pouring of the drum.

This particular drum showed excessive scoring and gave less than 50,000 service miles. A correctly made drum of similar structure and physical properties but completely free from this slag impurity gave 160,000 service miles.

Many examples have been noted where the presence of large amounts of manganese sulphide have been shown to exert a harmful influence on the wear resistance, and a little thought will indicate why this is so.

Thermal Cracking

This refers to a visible network pattern of cracks appearing over the surface of the drum. Photomicrograph, Fig. 11, magnified 10 times, represents the inside of a failed drum. Fig. 12 shows this same surface after polishing carefully, magnified 50 times. This latter illustrates the relation of the graphite to the network of cracks.

When a brake is suddenly applied, the surface of the drum tends to expand but is constrained by the adjacent cooler metal so that expansion can take place in one direction only, thus setting up stresses of such magnitude that incipient cracks are started, surface particles spall off, and the structure of the surface of the drum may be entirely changed to a completely soft or very hard material according to the kind of cast iron used and the severity of the braking conditions, etc.

The expansion and contraction in itself would not be so important an influence were the heat rapidly and uniformly dissipated and if the expansion and contraction were of simple form. Unfortunately, both cast iron and steel when heated pass through a cycle of opposing volume changes. To temperatures of 1360 deg. F., which is the approximate commencement of the carbide critical change point, there is a steady expansion. At 1360 deg. F., however, expansion gives way to a shrinkage, and this continues until the whole of the carbide has passed into solid solution. This may continue to temperatures of up to 1460 deg. F. depending upon both the composition and rate of heating. Above this temperature the iron begins to expand again.

On cooling, the reverse occurs but the critical carbide change point is lower on cooling than on heating, and instead of continuing to contract the iron begins to expand.

Thus, on rapid heating and cooling, the surface layers of the drum pass through a cycle of volume changes that may be so opposing that, when the immediate outer layer may be expanding, the underlying material may be contracting, or the outer layer may be contracting when the underlying material is expanding; while on cooling, the outer layer may be contracting while the underlying material is expanding, and but a few seconds later the outer layer will be contracting and underlying material expanding.

In addition to suffering these violent and opposing volume changes, cooling may be so rapid because of weather conditions or the use of cooling water that the surface structure of the drum may be drastically changed if the base matrix of the drum were of the type of pearlite that was reasonably stable to heat influences. Photomicrograph, Fig. 13, displays the structure of this drum before service at 1000 magnification and which structure is in every way satisfactory.

Photomicrograph, Fig. 14 shows the structure of the surface of this drum at the thermal checks. The pearlite is now replaced by a fully hardened coarse martensitic structure. The condition of heating to produce this structure must have been well over 1600 deg. F. and the whole of the surface of the drum had become file hard.

On subsequent operations, such a hardened brittle surface sloughs away and a fresh semi-hardened cracked surface remains.

On the other hand, if the original drum structure contains free ferrite such as shown by photomicrograph, Fig. 6, the remaining carbides may decompose into more free ferrite and the drum will become so soft that its wearing properties will be reduced to zero.

In addition to suffering these violent and opposing volume changes on heating and cooling and the carbides dissociating into ferrite and graphite, there may be a further structural change in the form of a swelling and lengthening of the graphite flakes themselves.

It is a simple matter to grow cast iron 50 per cent of its original volume by repeated heating and cooling above the critical change point, and this in itself results in a rapid disintegration of the metal structure and lowered physical properties.

Growth, in the full sense of the term, may be only a minor influence in the formation of heat checks in a brake drum yet, bearing in mind that we are dealing with contact metal surfaces, growth as a phenomenon of the surface of the brake drum cannot be ignored, for the graphite flakes must be regarded as minute cracks and every extension of these minute cracks means larger and larger cracks which ulti-

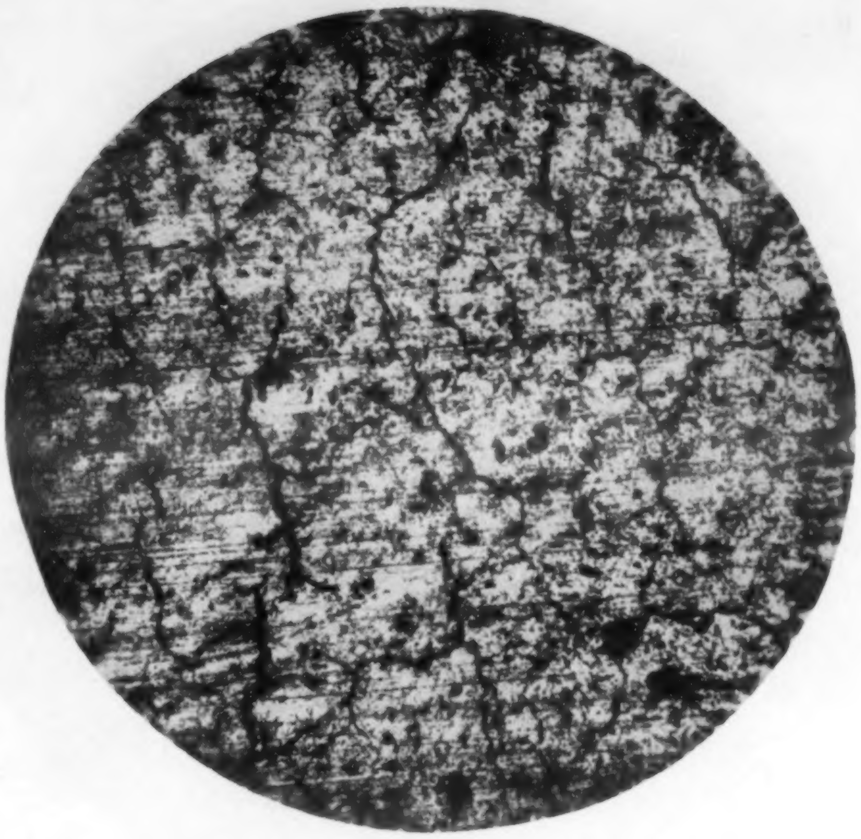
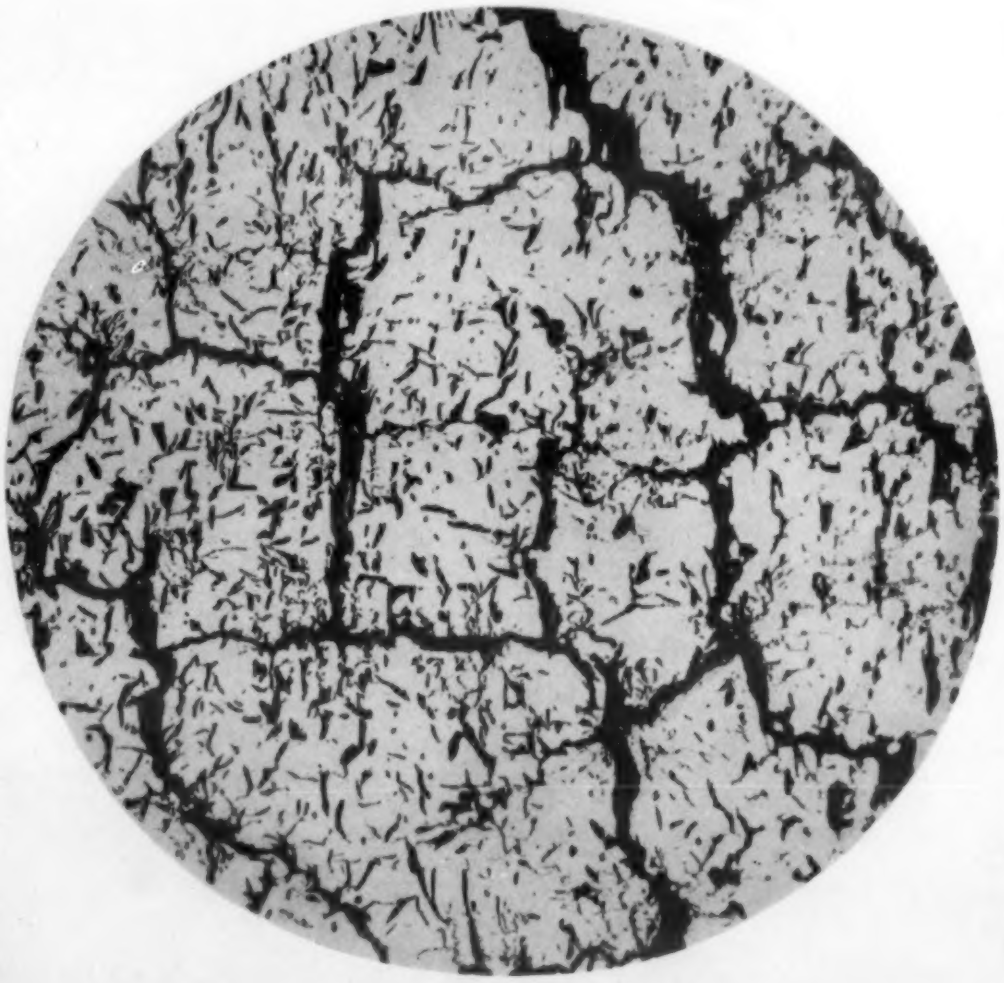


Fig. 11. Thermal cracking on the surface of a brake drum. 10X.

Fig. 12. Same as Fig. 11 after etching. Shows relation of graphite flakes to thermal checks. Reduced 1/3 from an original of 50 dia.



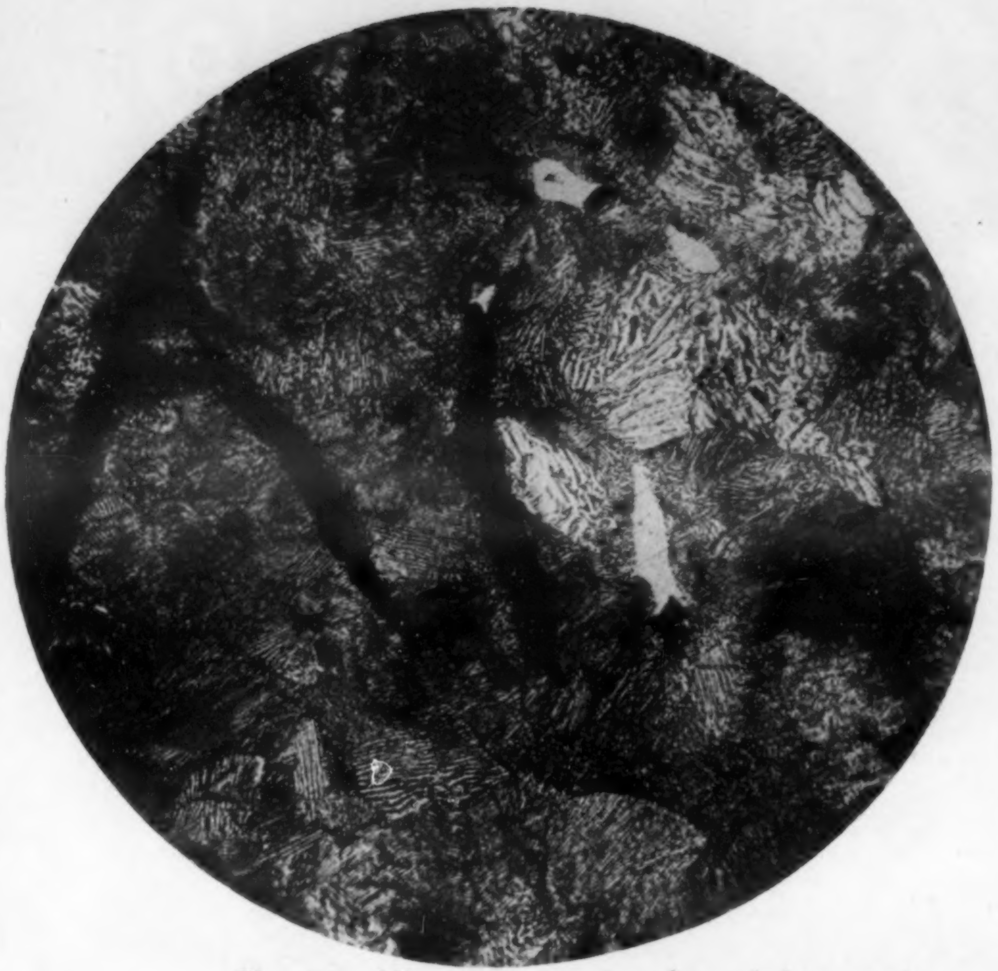
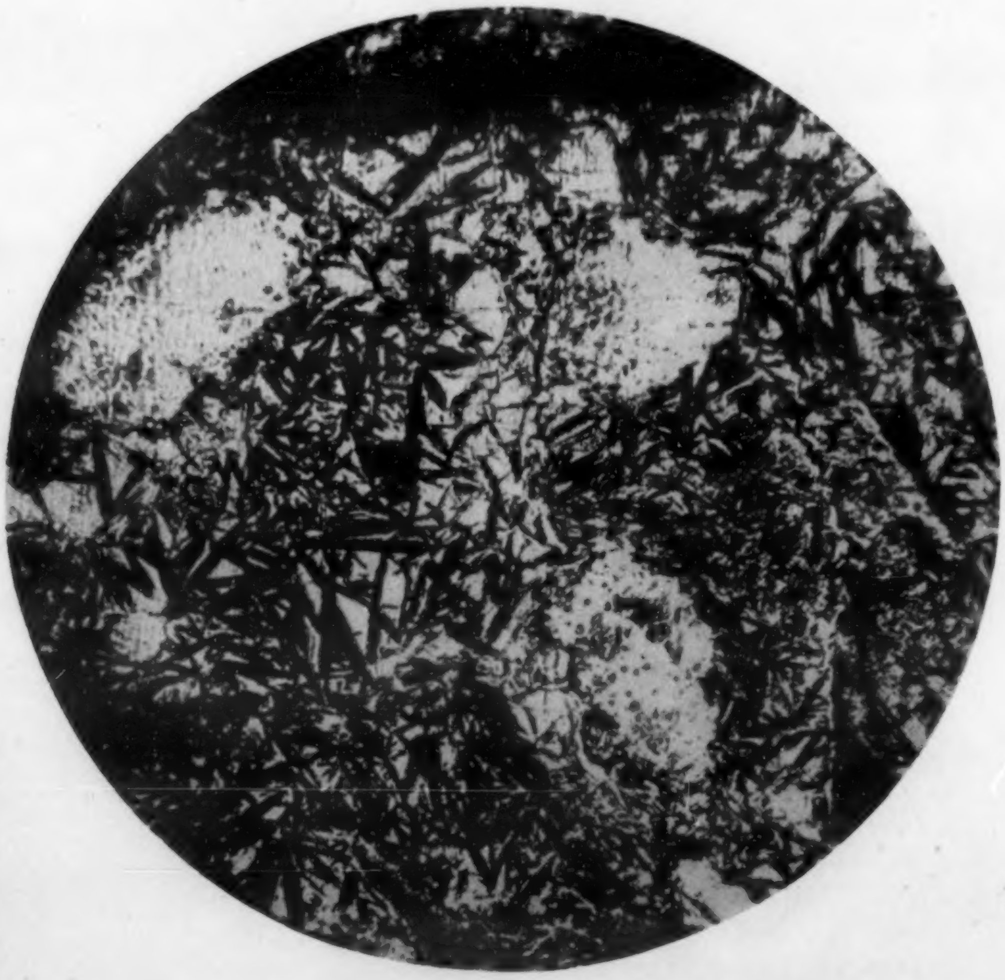


Fig. 13. Microstructure of a drum before service. Reduced 1/3 from an original of 1000 dia.

Fig. 14. Microstructure of surface of same drum (as Fig. 13) at surface checks. Reduced 1/3 from an original of 1000 dia.



mately lead to the series of networks of main cracks as shown by photomicrograph Fig. 12.

With such conflicting and opposing contending forces and changes of structure, it will be appreciated that not only the quantity and form of the graphite in the original drum castings but also the form and stability of the structure of the matrix have a profound influence on the life of any brake drum.

From all of this it will be seen, therefore, that any attempt to correlate and evaluate the quality of a brake drum iron with actual service life is a difficult matter. Any endeavor in this direction must be done under closely controlled conditions that bear some relation to the mechanical features of braking that are to be used and to the conditions likely to be encountered in service, but avoiding such extraneous influences as are imposed in actual road service and which cannot be tied directly to a brake drum metal problem.

Accordingly, a series of drums were given dynamometer tests through the courtesy and cooperation of the Timken-Detroit Axle Co. The test procedure was as follows:

Scoring Test:

1. Wheel load, 6,500 lbs., giving a total load on rear axle of 13,000 lbs.
2. Speed 365 r.p.m. equivalent to 40 miles per hr.
3. 53 lbs. air pressure on each cam face which, when using a 24 sq. in. diaphragm and a 5 in. operating lever, exerts 6,400 lbs. on each cam which is, in turn transmitted to 90.25 sq. in. of brake lining on each shoe or 71 lbs. sq. in. pressure on the lining surface.
4. A stop is made every 1½ min. from the above speed of 40 miles per hr.
5. Brake is for 9 secs. of applied direct energy stopping in 5 secs., with pressure kept on drum for 4 secs. distortion period. Deceleration rate is 11 ft. per sec.
6. Maximum temperature during brake application at point halfway through drum surface 655 deg. F. having a low of 575 deg. F.
7. Lining was Ra-Bestos 3202-A and a new lining was used on each drum test.
8. 1000 stops were made for each test.

Thermal Check Test:

Duplicate new drums were used for the heat checking test, and the foregoing procedure was modified as follows:

1. No change.
2. Speed 465 r.p.m., equivalent to 50 m.p.h.
3. 85 lbs. per sq. in. air pressure on 24 sq. in. diaphragm on 5-in. lever.
4. Stop made every 3 mins. from speed of 50 m.p.h.
5. Brake pressure on for 18 secs., stopping time being about 7 secs. thereby maintaining a 11-sec. distortion period. Deceleration throughout the test was approximately 11 ft. per sec.
6. Maximum temperature during brake application at a point halfway through drum had a maximum of 600 deg. F. during brake application with a minimum of 490 deg. F.

7 and 8. Same as scoring tests.

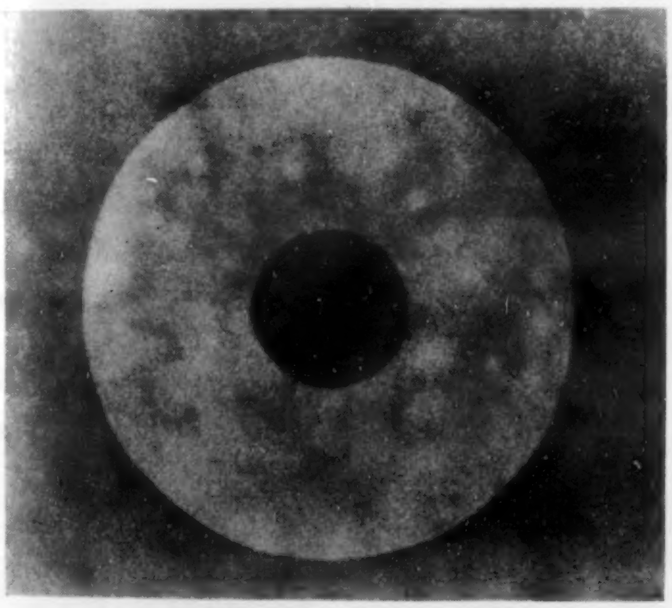
Comparing these two procedures, it will be observed that the temperature variation during the braking cycle was greater for the dynamometer test than for the scoring test.

(To be continued)

Letters to the Editor

Radiographs and Intensifying Screens

To the Editor: It has been brought to our attention recently that gamma-ray radiographs, exposed *without* intensifying screens (either lead foil or calcium tungstate), may show a mottled or streaked pattern which does not belong to the object radiographed. From our studies of this effect, we have concluded that it arises from secondary electrons generated in the protective lead backing of the cassette or film holder. These electrons reach the film through the intervening layers of felt or paper and adhesive material.



These layers are not uniform in their absorption of the secondary electrons, and are apt to cast a mottled or streaked shadow upon the film.

Exposure times may be materially reduced, and contrast increased, by the use of lead intensifying screens for gamma-ray and high-voltage exposures. There is little reason, therefore, for not using lead screens in contact with all films exposed to gamma-rays and supervoltage X-rays. The back lead foil screen will absorb any electrons emitted by the protective lead in the back of the film holder or cassette.

ROYAL G. TOBEY
Physics Department, Research Laboratories
Eastman Kodak Co., Rochester, N. Y.

A Note on Powder Metallurgy

To the Editor: During the engineering defense course in powder metallurgy, given by the writer during the summer at the College of the City of New York, a peculiar phenomenon was noted. Several explanations have been suggested, but none which seems to cover all the facts adequately.

The students were assigned a series of experiments to illustrate the effect of temperature variation in the heating cycle upon products made by powder metallurgy technic. An intimate mixture of 90 parts copper, 10 parts tin, 2 parts graphite was made. To this was added one per cent of Sterotex (Trade name of finely divided stearic acid, used as a lubricant for pressure molding.) and the whole pressed in a die at 40,000 lbs. per sq. in. to produce a cylinder approximately 0.5 by 0.8 in. These briquettes were subjected to heat treatment in a reducing atmosphere for 15 mins. All factors were kept constant except the temperature, which varied in each experiment by about 30 deg., and covered the range from 640 to 950 deg. C.

In each experiment 10 cylinders were made and tested and several check runs were made. The results, as expected, indicated an optimum temperature of about 810 deg. C. From lower temperatures to this point densities increased slightly, hardness more noticeably and break strength in steps to about 70 per cent above the strength of briquettes heated at the lowest temperature. Above 810 deg. C., again as expected, there was a sharp decrease in strength and hardness, a greatly increased percentage expansion and a sharp lowering of density.

But at 950 deg. C. a new factor entered the experiment. This temperature is high enough to melt a eutectic bronze, 90 per cent Cu, 10 per cent Sn. Since the original mixture was of a composition closely approximating this, it might be expected that the cylinders would collapse and fuse to an indeterminant mass. Instead, when they had cooled sufficiently for examination, no change was immediately apparent. Close examination revealed that they had retained their form so closely that the irregularities of the mold, such as a fine fin or flash at the base, less than one mil in diameter, retained perfect sharpness. The only change in appearance was a slight sponge-like roughening occurring on one or both bases which extended from the periphery for from one to two-thirds of the way toward the opposite circumference.

Although, however, there was no apparent change, a very decided change had occurred. The cylinders had lost more than 25 per cent of their weight, and their density had decreased 38 per cent. They had shrunk slightly more than the maximum expansion of similar products heated up to 810 deg. C., about 1.7 per cent. Beside them on the floor of the oven, lay a number of bronze pellets from about 1 to ¾ in. in their long dimension and from 1 to ⅜ in. at their thickest point. The weight of these quite exactly accounted for the weight lost by the cylinders. Analysis revealed that these pellets consisted of a 90-10 bronze, for which they met such tests as density and hardness.

The strength of the cylinders was low. They broke under loads less than half as great as for cylinders heated at 810 deg. C. They gave negative readings on the Rockwell hardness tester. But their structure was uniform. Porosity could be observed only under the microscope. Cross section studies were made both longitudinally and diagonally, a few thousandths of an inch apart, until the entire cylinder was sectioned, but neither the interior nor the surface revealed any irregularity nor the slightest indication of blow-holes unless we arbitrarily define the slight surface roughening on the bases as blow-holes.

It is, of course, self-evident that the pellets exuded from the cylinders and probably roughened the bases during this action. But it is difficult to conceive of any process which would release one quarter of the original weight of these briquettes, without markedly deforming them. It is just as difficult to explain a selective fusion which does not deform even slightly the delicate wire-like flash formed on the base during the molding operation. Any explanation must take into account, moreover, that the pellets and the finished cylinders are both of the same chemical composition as the original briquettes except that there is a concentration of graphite in the cylinders. Neither chemically combined nor mechanically occluded graphite is present in the pellets.

That surface tension held these cylinders in form is indicated by the fact that if the surface be broken by a light external force while they are held at the elevated temperature, the cylinders collapse and expose a molten center. But since the pellets exude from the hot cylinders, they must have exerted internal pressure at some time during the process, and at some time the surface must have been discontinuous. None the less, there is no evidence of internal nor surface blow-holes, in these cylinders.

The matter is reported as a phenomenon peculiar to powder metallurgy.

WALTER J BAËZA
President
Industrial Research Co., New York

A FEW CHUCKLES

The Successful Designer

This poem while it has been published elsewhere, is believed to be worthy of further publicity:

The designer bent across his board,
Wonderful things in his head were stored,
And he said as he rubbed his throbbing bean,
"How can I make this thing tough to machine?
If this part here were only straight
I'm sure the thing would work first rate,
But 'twould be so easy to turn and bore
It never would make the machinists sore.
I'd better put in a right angle there
Then watch those babies tear their hair.
Now I'll put the holes that hold the cap
Way down in here where they're hard to tap.
Now this piece won't work, I'll bet a buck,
For it can't be held in a shoe or chuck;
It can't be drilled or it can't be ground,
In fact the design is exceedingly sound."
He looked again and cried, "At last!
Success is mine, it can't even be cast."

F. RANKIN WEISGERBER

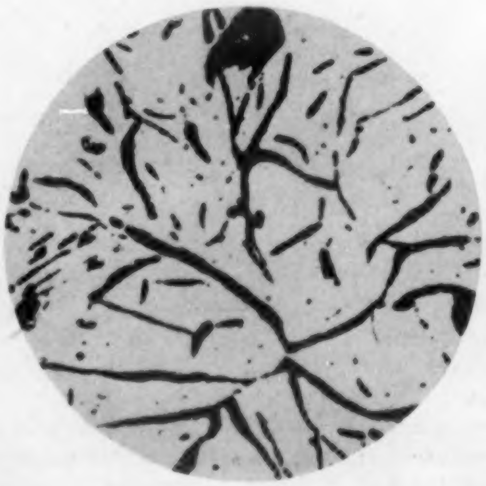
Hot Boiling Water!

> *Steel* for July 28, page 72, describes a "plastic mender for metals that withstands the heat of boiling water and direct flame. In laboratory tests, repairs made on ordinary aluminum pots and pans withstood 100 hrs. of boiling at temperatures reaching 2000 deg. F."

That's hot boiling water all right; also aluminum melts at about 1215 deg. F.—H.W.G.

A Chuckle on Us!

See METALS AND ALLOYS, July, 1941, page 84. "Flowability of molding sands—2,000 gage." 2.000 was meant
—H.W.G.



"Uncle Bim"

To the Editor: We are enclosing herewith a photomicrograph which appeared in a nationally distributed pamphlet on cast iron. The likeness of "Uncle Bim" will be seen at a glance. Perhaps "he" has formed a Zanderproof shelter.

R. DRANT
General Mgr., Sorbo-Mat Process Engineers, St. Louis.

METALLURGICAL ENGINEERING news

Equipment • Finishes • Materials • Methods • Processes • Products
Alloys • Applications • Designs • People • Plants • Societies

The Production Front

by H. R. Clauser
Assistant Editor

ACTIONS AND SIGNS of future action all along the "production front" last month seemed to indicate that our ponderous industrial machine was at last approaching real all-out war production. The President's appointment of a single man to direct and coordinate the war effort was a necessary and essential action towards gaining maximum production. Increased concentration on the job of converting non-essential products plants to war work, and the fact that the country—the government, industry and the people—was becoming increasingly scrap conscious, indicated the trend of things to come.

The War Production Board

The most significant action of the month was the creation of a single, unified war production board and the appointment of one man, Donald Nelson, to direct the vast war program. Although there was little change in personnel and no revolutionary changes in organization, the importance of the action lay in the definite delegation of top authority to one man who, in turn, will pass it on to the six "branch" chiefs under him. Under such a system decisive, authoritative action is possible—something sadly lacking in the previous set-ups.

The six main divisions, which will proceed under the direction of the War Production Chief, are: purchases, production, materials, industry operations, labor and civilian supply. A seventh division to coordinate all the activities related to priorities and contract distribution in the field will probably also be organized.

Out of all this reeshuffling of authority and organization, there has come one much-needed committee, to be known as the Requirements Committee. It has received little fanfare, but its functions are among the most important in the entire war program. This committee, which is actually in the Materials Division, is made up of representatives from all the various groups that represent the total demand for available materials.

The main groups represented are: Lend-Lease, Economic Warfare, Civilian Supply, the Army and Navy, and the Maritime Commission. It is the function of this committee to administer the allocation system whenever the requirements for certain materials exceed the demand; it will allocate to the various groups represented on the Requirements Committee according to the importance of their demands. From that point on, it is the job of each group through the use of priorities to allocate to individual plants.

Among the first jobs undertaken by the War Production Board was the initiation of a thorough and detailed statistical study of the metals industries. To the desks of metal producers, fabricators, processors and finishers already loaded with requests for information, went another questionnaire asking for reports on the uses of more than 250 shapes and types of metals. On the basis of this study, WPB hopes to be able to govern the distribution of critical and strategic materials beginning April 1.

Conversion from Peace to War

All over the country last month the shift from non-essential production to war output gained impetus. The War Production Board "got tough" and indicated that no help would be forthcoming to those non-essential industries who made no effort to tie in with the war program.

For the small manufacturers who desire war work, a new plan, known as the Modified Production Requirements Plan, was inaugurated, designed to obtain priority assistance more quickly and easily to meet their needs for scarce materials. Besides this, a series of clinics have been organized to facilitate the fulfilling of requests from thousands of small manufacturers who are seeking conversion information.

Many metal working plants have already successfully switched to essential war products. One washing machine manufacturer has turned to producing anti-aircraft machine-gun mounts; a chain-manufacturing company is machining turrets for light tanks; and a large railroad car plant is now one of the foremost shell factories in the country.

After many months of time wasting in wrangling over the problem of whether or not to convert the auto plants to all-out war production, and if so how and by whom, decisive action was taken last month. Ernest Kanzler, former Ford production chief, got the nod from WPB, to head-up the tremendous job of totally converting the automobile industry's production to war products.

In most conversion projects, the task of retooling is the biggest job, and everything is being done to expedite the production of these essentials. Machine tool and machinery producers have been promised full priority aid. In order that the finished tools be delivered where the need is most urgent, a revised preference list has been drawn up, and as precaution against price instability, the OPA has placed a price ceiling on all machine tools which, according to the new schedule, include all machines for the cutting, abrading, shaping and forming of metals.

Non-Ferrous Metals

Last month saw a general tightening of the already severe restrictions on a long list of non-ferrous metals. The nation's

(Continued on page 270)

The Installation and Care of Refractory Linings in Ajax-Wyatt Induction Furnaces

Among electric furnaces widely used in the metallurgical industry, the Ajax-Wyatt vertical ring induction type electric furnace is recognized as giving economical operation, close temperature control and thorough mixing of the metals.

Sometimes the weakest part of a melting furnace is its refractory lining. No one refractory material will meet every condition. But whatever lining material is used, its service will be lengthened and improved if it is skillfully installed and properly cared for while in operation.

The following notes on installing a lining, particularly on methods and tools, may prove helpful.

Figure 1 shows a section of a refractory lining taken from a furnace after failure. The cut, showing the results of faulty lining practice which led to the failure, clearly exhibits some of the faults:

1. As installation progressed, the top surface of each layer was not thoroughly roughed up, before material for the next layer went into the mold. Layer cracks resulted.

2. Some of the layers are too thick. A finished layer should not be *more* than 2″ thick, to prevent improper packing and a soft section —and not *less* than 1½″, to prevent "over-ramming" and cracks.

3. The ramming of the crucible bottom was insufficiently tight. This permitted molten metal to penetrate between the layers of refractory material.

Equipment. Of prime importance is a rigid support for the shell while the lining is being rammed. The foundation must be solid and the shell must be well braced. Otherwise vibrations in the mass during ramming will cause cracks to form.

Figures 2 and 3 show typical ramming tools. The butt with the roughened face is desirable because it does not leave a flat surface. Using it to roughen the layer surface slightly, the succeeding layer of cement will knit firmly. A necessary tool not illustrated is one for gouging the surface of rammed layers. This tool can be easily made by forming a chisel face on the end of a piece of strap iron. A convenient size for this tool is 3½ feet long, 2″ wide and ¼″ thick.

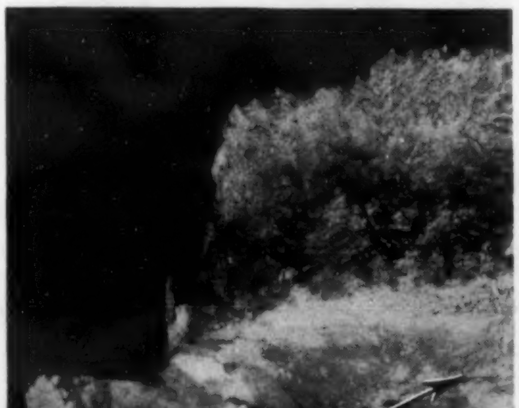


FIG. 1 *A Section of a Refractory Lining Taken from a Furnace After Failure*

Forms. These must be of solid construction. Metal forms are suggested for the crucible and for the primary coil hole. Forms should be as light in weight as possible consistent with strength to withstand, without movement, the severe impacts of the ramming tool. The construction should be simple, for easy removal from the rammed piece. A wooden form for the secondary channel is sufficient and it should be hollow so that it can be burned out from the completed block.

Insulation. Only a medium degree of refractoriness and medium mechanical strength is necessary in the insulation. It is preferable to use a material that can be readily shaped to fit the shell.

Refractory Ramming Mixtures. The specific refractory mixture or cement is governed by the type of alloy or metals to be melted and upon the sequence of furnace operation. It should have a good degree of workability, high refractoriness and low shrinkage. Failures frequently occur through lining shrinkage at high temperature. A slight permanent expansion under heat is an advantage.

Preparation of the Cement. Mechanical mixing is recommended. The cost of such a mixer need not be great. It assures even distribution of water throughout the mixture, . . . permits preparing the mixture as it is used . . . saves considerable labor, over hand mixing.

Hand Mixing of Cement. If a mechanical mixer is not available, prepare a clean space of about 150 square feet on a hard surfaced floor. The mixed cements or the ingredients should be dumped thereon and the pile leveled to a depth of about 6″. With a sprinkling can, about one-half of the required water should be evenly distributed over the cement. This pile should be turned over once and the remainder of the water added.

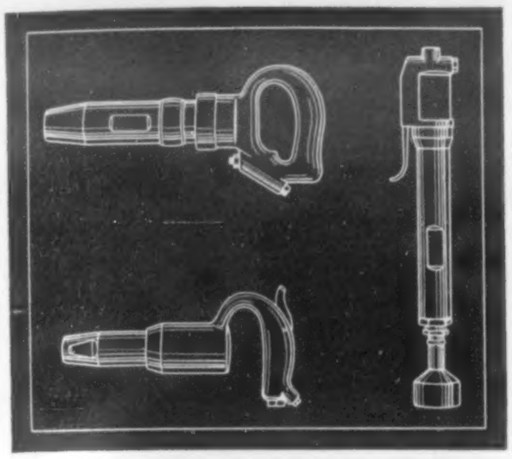


FIG. 2 *Typical Pneumatic Hammers for Use in Ramming Linings*

After turning the cement water mixture over two or three times it should be passed through a #4 to #6 mesh foundry riddle. This breaks up the large lumps and helps to distribute the water evenly. After screening, the mixture should be turned over once more on the floor and then stored in covered metal containers.

Installation. Because vibrations during ramming cause lining cracks, too much emphasis cannot be placed on having a solid foundation. The bottom casing of the shell must rest solidly. If, as frequently happens, the casing rests on the four corners of a cradle a firm wedge should be driven between the bottom of the casing and the solid floor.

Once the insulating material is in place, the previously prepared and moistened cement should be poured into the mold to a depth of approximately 3″. The mixture should then be rammed with a rivet hammer using the waffle type butt (figure 3). The 3″ layer will ram down to a thickness of about 1½″. Thoroughly rough up the top of this finished layer to a depth of ¼″ and add the next layer. This practice should continue until the bottom is sufficiently built up to support the point of the V channel form.

This form, for the secondary coil, should be clamped firmly in position and ramming continued until the bottom of the space for the primary coil is reached. Now the clamps can be removed and the secondary form need have no further support. The form for the primary coil must be clamped in position and the transite forms for the sides of the blocks put in place.

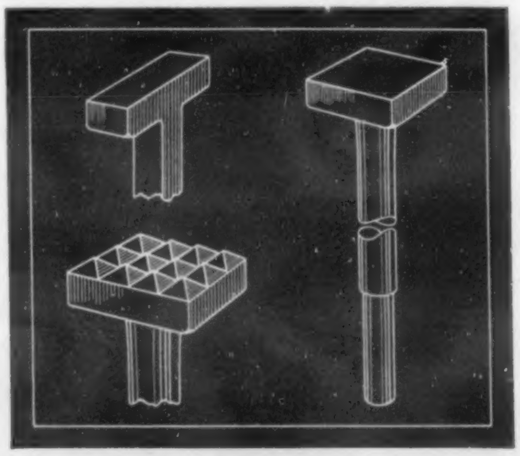


FIG. 3 *Commonly Used Shapes of Ramming Tools*

Ramming can then continue but great care should be exercised to do a skillful ramming job, particularly around the form for the primary coil, since this is one of the weakest points in the lining.

Precautions

1. Make sure the cement is thoroughly mixed and sufficiently wet for proper ramming. Avoid the use of too much water.
2. Make certain that the shell rests on a solid foundation and is well supported.

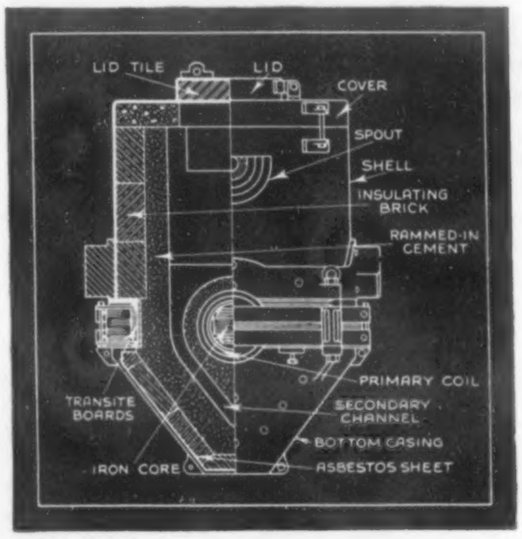


FIG. 4 *Diagrammatic Sketch of Ajax-Wyatt Furnace*

3. Make certain that the top of each layer of cement is well roughed up before adding more material.
4. Make sure that the cement is well tamped in around the primary and secondary forms.
5. Wherever possible use a waffle-faced tool to insure a good knit and a roughened top surface.
6. Be sure that all bolts in the shell are thoroughly tightened.
7. Take particular pains in ramming the crucible bottom. The object is to eliminate cracks and spaces where molten metal will penetrate.

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Refractory Shapes and Cements of
CRYSTOLON (silicon carbide); ALUNDUM (fused alumina); and Fused Magnesia Grains

NORTON COMPANY, WORCESTER, MASS.

entire supply of aluminum was earmarked for war production. The order, issued by Donald Nelson, limited the metal to only fifteen uses, almost all of which are tied in with war contracts. There were quiet rumors, gaining in intensity, that similar action would be taken to clamp down just as tightly on many other vital and scarce metals.

Nickel, brass and copper have already been subjected to further limitations; their use in the manufacture of non-essential incandescent lamps was ordered cut approximately 50 per cent. An additional order will eliminate the use of brass for shoe eyelets, hooks, tacks, etc., which will save enough brass to make a million ordinary artillery shell cases a year.

Cadmium, vital in plating parts to resist corrosion and used in instruments for planes, tanks and ships, has been put under stricter control, and many non-essential uses have been banned. Chromium, so necessary for corrosive and heat resistant steel, is gradually being limited to vital military needs. Lead, after April 1, will be practically unattainable for non-essential products. Tin is likewise being squeezed.

A program long contemplated was launched last month to step up the domestic production of copper, lead and zinc. Premium prices will be paid for these metals in excess of the set quotas. There will also be a rise in the ceiling price of lead. The rate of production of lead and zinc through these efforts is expected to be increased 30 per cent.

There still remains the need for increase in domestic production of high grade manganese. In 1940, 1,282,079 tons were imported, a considerable portion of which came from the Far East. Our domestic production amounted to 40,000 tons in 1940.

Research is being carried on to increase this production figure by the U. S. Bureau of Mines as well as the research staff of the Tennessee Valley Authority at Norris Dam. A plant near Las Vegas, Nev., promises a production of 100,000 tons annually by December. All this indicates that the manganese problem is recognized and is being worked towards a solution.

Scrap, Salvage and Reclamation

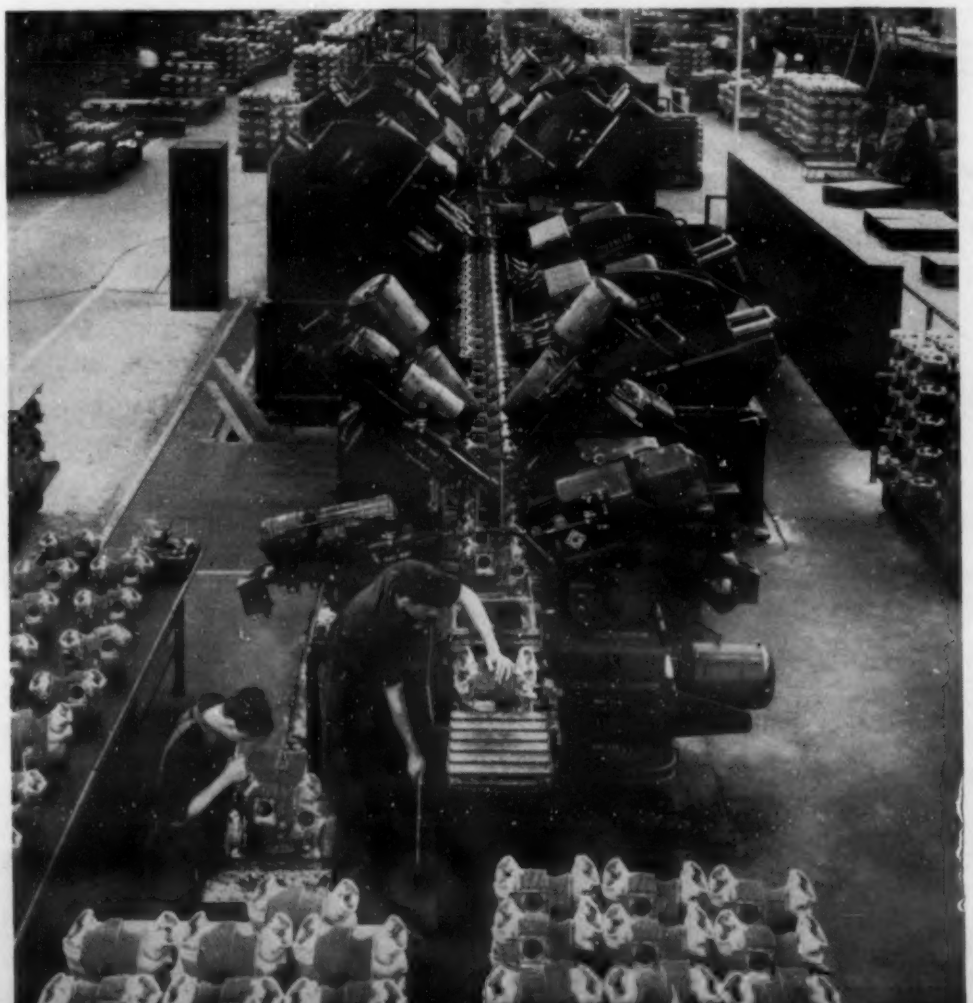
Scrap, ferrous and non-ferrous, remains a major obstacle to the metal industries in reaching maximum production. Its extreme importance to the effective functioning of our war machine caused the war agencies to seek, plan and devise means of alleviating the situation last month.

The shortage of scrap steel continued to influence steel operations, and claims that the automobile wrecking yards were not producing the maximum amount of scrap possible were prevalent. True or not, the Bureau of Industrial Conservation began an intensive drive to collect all available iron and steel scrap from auto graveyards within six months. It is estimated that the four or five million old cars in junkyards scattered throughout the country will yield around 3,500,000 tons of scrap—enough for use in the production of about 6,500,000 tons of steel.

In the production of most non-ferrous metals, scrap is an important ingredient. About a quarter of all the lead consumed in the United States this year will come from scrap; 30 per cent of all brass production comes from scrap. In order to keep copper scrap in constant movement into the most vital war industries, fabricators, with the exception of railroads and utilities, were ordered not to use or remelt their own scrap without specific authorization. New price ceilings have been placed on secondary lead to stimulate scrap collection.

Tin scrap has been placed under priorities control, and segregation of aluminum scrap by alloy content and forms is now mandatory. Segregation makes possible the reprocessing of aluminum scrap into high-grade materials required for military needs. It is reported that 100 per cent segregation of sheet scrap alone will provide, at the rate of production next July, enough high-grade aluminum each month for several hundred airplanes, and at the same time save enough magnesium for use in thousands of incendiary bombs.

The United States is becoming scrap conscious. Campaigns for the salvage and reclamation of vital metals are in progress all over the country. Many plants are utilizing reclamation systems, which are capable of reclaiming as high as 10 to 25 per cent of otherwise wasted materials. Several cities have set up organized and detailed plans for saving raw materials, and salvage committees are underway in 16 states and the District of Columbia.



Mass Production of Airplane Cylinder Heads

At the Cincinnati airplane engine plant of the Wright Aeronautical Corp., Paterson, N. J., a huge Greenlee automatic transfer machine is being used for the mass production of cylinder heads. Reduced to its simplest terms, this massive machine may be considered as a series of individual, multiple-spindle machine tools arranged along both sides of an automatic conveyor.

Actually, there are two machines set up, one behind the other, to form one continuous production line. The first part is 21 ft. long; the second machine is 73 ft. in length. Altogether there are 72 stations, 33 of which are active or operating stations; the rest are bridges and gaging stations.

The photograph shows a rear view of the Greenlee machine and completed cylinder heads being removed.

Electromagnetic Strain Gage

A new type of electromagnetic gage to measure the strain on machine parts subject to sudden loads has been developed by *General Electric Co.*, Schenectady, N. Y.

In some types of machines, such as punch presses, shears and press brakes, the strain during a cycle of operation occurs for a very short period of time—rising abruptly to the maximum and then falling sharply to zero. It is this kind of machine for which the gage has been developed as a protective device to forestall breakage of the machine.

It can be connected so as to give more than one kind of indication. A direct value of the maximum strain can be obtained from an instrument in front of the operator. A light or bell can be attached so as to give a signal when a pre-determined amount of strain has been reached.

The gage need not be applied directly to the vital part of the machine under strain but it can be applied to any part of the machine whose stress represents the equivalent stress on the vital part.

The essential parts of the gage are a gage rod, lever arm, and head. The rod is fastened to the machine at either end in the direction of the strain. The lever arm, attached at its outer end to the machine, is at right angles to the rod. The gage head is mounted on a plate that also is attached to the machine at a point on a line with the lever arm. The gage head consists of an armature operating within two coils.

Before the job is started, the position of the armature within the coils is adjusted so that a zero reading is registered on a connected instrument. When the machine is put into operation and strain exerted, the rod pulls down on the lever arm. The arm in turn pulls down on a pin in the armature and moves the armature to a new position within the coils.

This affects the electromagnetic relationship between the armature and coils in accordance with the amount of strain exerted. The instrument, previously calibrated against known strain loads, then indicates to the machine operator the extent of the unknown strain.

Bright Hardening of Tool Steels

A new heat treating process, recently developed, in which the surface conditions are controlled during the entire heat treating cycle, has been announced by *Alfred Heller Heat-Treating Co.*, New York.

The process, known as "silver finish" hardening, is said to guarantee 100 per cent freedom from carburization or decarburization on any analysis of steel, provided 2000 deg. F. is not exceeded in any stage of the heat treating process.

In the heat treatment of drawing dies, forging dies, die casting dies, etc., it is important to maintain perfect surface conditions both for finish and analysis. Since the "silver finish" process affords complete protection throughout the heat treating cycle, a polished part will have practically the same polish after treatment as before treating, and the surface analysis will remain unchanged because the absorption of any harmful gas, such as nitrogen or hydrogen, is made impossible.

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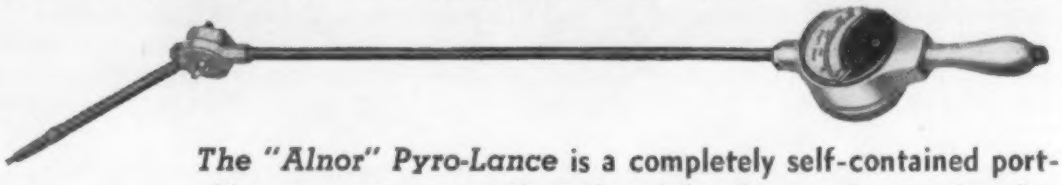

The "Alnor" Pyro-Lance is a completely self-contained portable pyrometer especially designed for the non-ferrous foundry. It can help you reduce costs by lowering scrap losses, cut fuel consumption, speed production by eliminating rejects.

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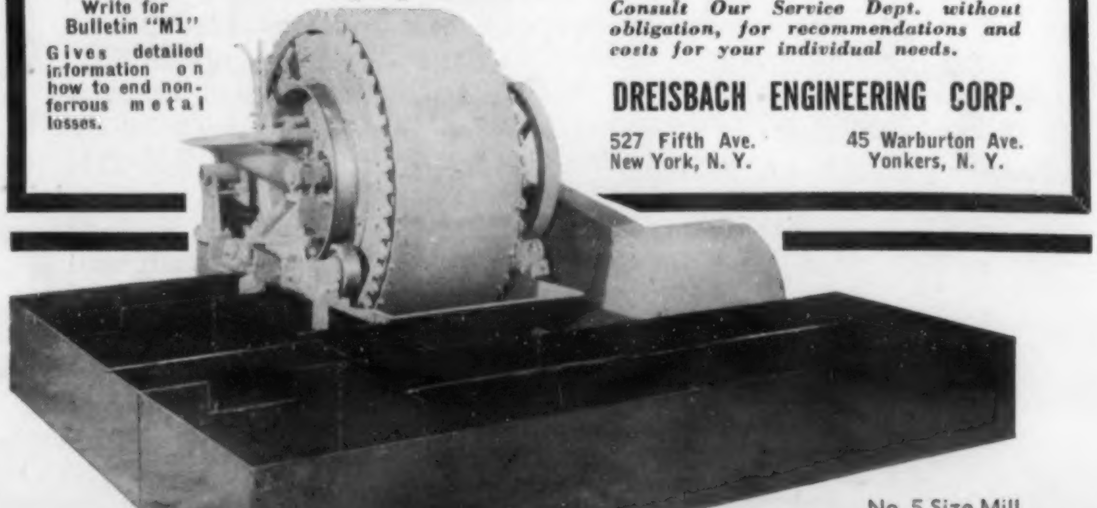


No. 5 Size Mill will mill 200,000 lbs. of skimmings and sweepings per month . . . one shift, one operator and a 5-H.P. motor and recirculating water.

Mass Production of Nitrided Tank Parts

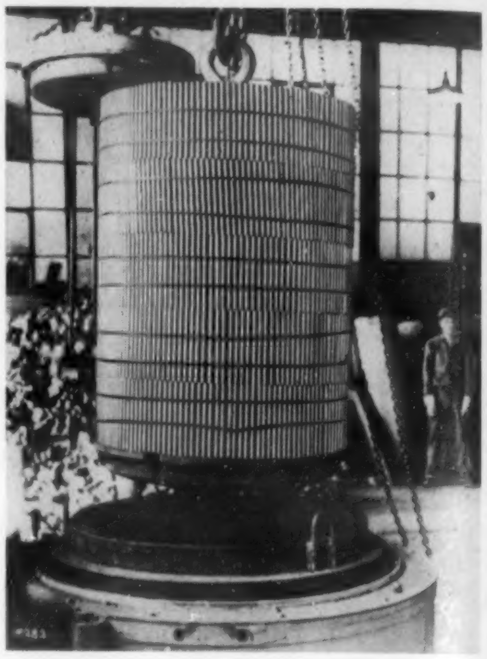
At the *Campbell Wyant & Cannon Foundry Co.,* Muskegon, Mich., tank tractor pins are being nitrided on a mass production basis. Loads of 12,000 lbs., containing 10,000 track pins, are being nitrided to a depth of 0.025 in. to 0.030 in.

The track pins are 9½ in. long x ¾ in. diam., and are used to tie the tractor shoes together, in much the same manner as a hinge pin. 140 pins are required for each tank, 70 per side. The pins are of Nitralloy "G" modified steel having the following approximate analysis: carbon 0.30-0.40; silicon 0.30 max.; manganese 0.40-0.60; chromium 1.40-1.90; molybdenum 0.15-0.25; aluminum 0.90-1.40 per cent.

Prior to nitriding, the pins are heat treated by oil quenching from 1650 deg. F. They are then drawn at 1300 deg. F. This treatment results in the following physical characteristics: 123,000-145,000 lbs. tensile strength; 15 per cent elongation in 2 in.; 45 per cent reduction of area; and 45 min. ft. lbs. Izod.

In preparing the load for the nitriding operation, a cylindrical fixture is used. The bottom layer of pins is set onto an alloy grid, which rests in the bottom of the cylindrical fixture. This bottom layer consists of 2000 pins solidly packed, and is held together with steel banding. Successive layers are handled in the same manner, and when the 5 layers are completed, the load is lifted from the fixture and lowered into one of the two furnaces.

Nitriding is carried on in two nitriding furnaces, manufactured by *Lindberg Engineering Co.,* Chicago. These are equipped with alloy retorts 38 in. diam. x 54 in. deep. Self sealing insulated covers are provided, and ammonia is introduced through pipes extending through the cover.



The furnaces are gas-fired, and are of the forced convection type, in which heated air is circulated under pressure and at high velocities.

End-to-end runout specifications on straightness are 0.010 in. maximum, and it has never been necessary to reject a pin due to warpage. Loads handled are staggered between the two furnaces so that one heat is available at the middle of the week, and the next heat at the end of the week. A weekly production of 20,000 pins is therefore turned out.

News of Metallurgical Engineers

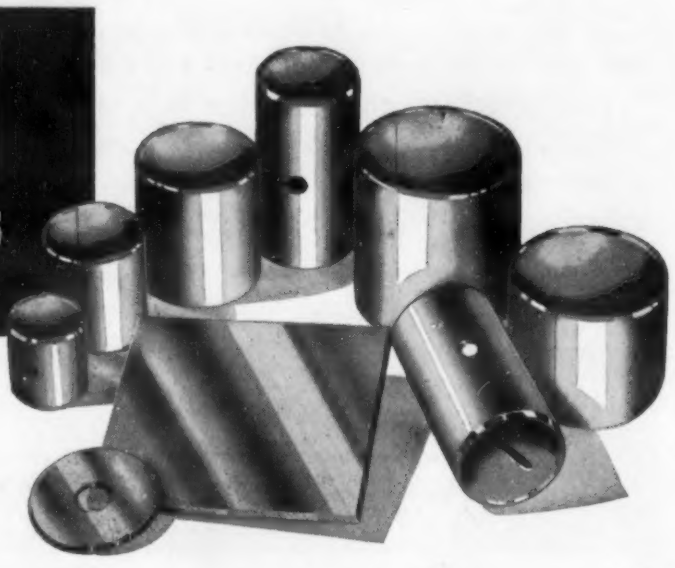
Four changes in the operating personnel of American Steel & Wire Co., subsidiary of U. S. Steel, were made recently: *Eugene J. Reardon* is now assistant chief engineer with headquarters at Cleveland. . . . *Stephen B. Metcalfe* succeeded him as general superintendent of the New Haven, Conn., and Trenton, N. J., Works. . . . *Alexander J. King* has been appointed superintendent at the Trenton Works and has been replaced by *Bernard N. Carlson* as chief rope engineer.

Battelle Memorial Institute has recently made several additions to its staff: *John G. Kura* has been named to the technical staff to do metallurgical research. . . . *J. Harry Jackson* has been appointed a research engineer and assigned to research in metallurgy. . . . *Charles A. Reichelderfer* has joined the research staff and will do work in the non-ferrous metallurgy division.

Arthur F. Braid has resigned as sales manager of Metal & Thermit Corp., where for 31 years he handled the engineering sales service of the company.

SOMETHING
NEW
in BEARINGS

by JOHNSON BRONZE



Pre-Cast Bearing
Bronze on Steel

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The bronze alloy—S.A.E. 64, in powder form—is permanently bonded to strip steel. The process of manufacturing bearings or bushings from *Pre-Cast Bearing* BRONZE ON STEEL is essentially a stamping and forming operation. As a result, few bearings are as economical as *Pre-Cast Bearing* BRONZE ON STEEL, particularly when there is production quantities.

Pre-Cast Bearing BRONZE ON STEEL is also available in rolls—up to 400 feet in length—or as plates, washers or various types of stampings. It will pay you to investigate this new type of bearing. A request, on your business letterhead, will bring you complete information plus a sample bearing. Write TODAY.

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Porous Iron Bearings

Keystone Carbon Co., Inc., St. Mary's, Pa., has announced the addition of "Self-lube" porous iron bearings to their line of self-lubricating bronze bearings. The new porous iron bearings are reported to be stronger than porous bronze bearings and are interchangeable with them in most applications. They were introduced to conserve copper.

The porous iron bearings are made from powdered iron, which is molded to size in the shape desired, then baked, and finally saturated with a good grade of oil. They have an average porosity of 25 to 35 per cent, enabling them to store a large amount of oil, which forms a protective, continuous oil film on the bearing surface.

In many instances, this oil reserve lasts the entire life of the application, eliminating the use of oil vents or grease cups. Additional lubrication is recommended for heavy duty or continuous operating units.

The new bearings have a low friction coefficient which, together with their self-lubricating qualities, prevents excessive temperature, speed reduction, noise and scoring of shaft. They are molded to close dimensional tolerances so that no re-designing or special engineering is required.

● *General Electric Co.,* Schenectady, N. Y., has announced that silvered glass reflectors will replace highly polished aluminum reflectors in its pendant shielding-type street lights. This move will conserve aluminum and produce an average increase of about 10 per cent in the efficiency of the luminaires. The glass reflector is strongly reinforced by a copperplated backing, which clings so tightly that even though the reflector should be smashed, the pieces of glass will not fall.

Spectrographic Analysis of Tin Impurities

An improved spectrographic method for analyzing tin for impurities, which greatly reduces the time required for the examination of samples of this critical and scarce war material, has been developed by the *National Bureau of Standards,* according to the Department of Commerce, Washington.

Under the new method, evolved by Bourdon F. Scribner of the Bureau staff, 6 samples can be analyzed in 2 hrs., compared with 2 days under the older wet-chemical method. The wet-chemical analysis of tin is difficult as well as time-consuming and, therefore, poorly adapted to the routine inspection of hundreds of samples.

By this method the tin is melted or compressed into electrode rods between which a high tension spark is passed, causing vaporization. The spectral lines in the vaporized metal are recorded on a photographic plate. The intensities of the lines of the various impurities are measured relative to control lines of the tin spectrum by means of a photocell and galvanometer incorporated in a micrometer. The relationship between impurity intensity line and concentration is plotted as a curve.

This method permits the determination of 10 impurities—antimony, arsenic, bismuth, cadmium, copper, indium, iron, lead, silver and zinc. The error is usually about 5 per cent plus or minus the amount present, but may be halved by close control of conditions. Small samples are used and uncommon impurities are certain to be detected.

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Important today is the fact that you can get LUMNITE and the suitable refractory aggregates just as readily as ever. This is an extra reason for using Refractory Concrete, which gives you:

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SPECIAL SHAPES of Refractory Concrete can be made in your own plant. You avoid operating delays caused by long waiting for specials. For full information on how to use Refractory Concrete to meet your requirements, write The Atlas LUMNITE Cement Company (United States Steel Corporation Subsidiary), Dept. M, Chrysler Bldg., New York City.

LUMNITE FOR REFRACTORY CONCRETE

Motor-Driven Oblique Plating Barrel

A new and improved oblique plating barrel drive has been developed by *Hanson-Van Winkle-Munning Co.,* Matawan, N. J. This type oblique barrel is now available in a new model, directly driven by a 1/6 h.p. motorized worm gear reducer, which is suitably mounted on the tank, already for connection to the user's power lines. The arrangement readily permits the removal of the cylinder for rinsing, loading and unloading of the work.

This barrel can be furnished with a wooden tank, asphalt lined; or a steel tank, unlined or lined with 3/16 in. vulcanized rubber. The cylinder is either of bakelite construction with disc- or button-type contacts; or of hard rubber with disc-type contact only. The panels in the bakelite cylinder are ⅛ in. thick; in the hard rubber cylinder, ¼ in. thick. This unit will handle about 25 lbs. of work per batch.

Check-Analysis Instrument

A new apparatus, known as the Identometer, just announced by *Metals Research Apparatus, Inc.,* Pittsburgh, is designed to make a very rapid check-analysis of metals and alloys by the use of a newly-developed form of thermocouple.

The instrument is said to be simple, both in construction and operation, which makes the instrument suitable for general use in laboratory and shipping room inspection, in the tool room, and for research work on new alloys.

To run a check-analysis, the metal sample to be tested is fastened by means of suitable clamps to silver contacts and held tightly against another, similarly-mounted "reference" sample of a known composition. A high current circuit built within the apparatus is then closed for about 2 sec. This brief period is sufficient to form a weld at the point of contact or along the line of contact of the two samples.

By means of a two-pole, double-throw rotary switch, the "welding circuit" is then opened and a galvanometer circuit instantaneously closed and allowed to remain so for the duration of the test. For most purposes, the time required will be about 1 min. If the galvanometer indicates the presence of a thermo-electric current, it is certain that the "test" sample and the "reference" sample are dissimilar. If the galvanometer remains at the "zero" setting, the two samples will represent identical materials.

Selenium and Tellurium Become "Useful"

Two metals, selenium and tellurium, for which there has been only a small demand in the past, have now found some important commercial uses, according to Drs. G. R. Waitkens and R. Shutt of *Battelle Memorial Institute,* Columbus, Ohio, in a report to the American Chemical Society.

Many industrial applications of iron castings, such as camshafts, gears, cast iron paving blocks, and railway car wheels, require that the surface of the casting be highly resistant to abrasion. Research has shown that only 4 grams of tellurium, plus graphite, added to a ton of iron, impart a much improved wear-resistant surface to the finished casting.

Small amounts of selenium and tellurium added to steel, copper, copper-rich alloys, and bronze, it is said, make them more easily cut and sawed in the machine shop. Tellurium increases the strength and hardness of tin. Selenium coatings adhere firmly to magnesium alloys and definitely reduce attack by sea water; this element also improves paint adherence, while selenium and tellurium compounds act as brighteners in some electroplating baths.

Selenium and tellurium combine with practically all metals. In the past, these elements have been regarded as objectionable impurities in metals and alloys, but recent studies prove this to be a fallacy. Properly used, they are beneficial.

Tellurium added to lead or lead alloys greatly improves corrosion resistance, and tellurium-lead actually increases in strength and toughness as it is rolled or stretched. Tellurium added to lead doubles its life in sulfuric acid plant construction.

● *Progressive Welder Co.,* Detroit, has recently developed a low cost installation for welding together ends of strips. It consists of two air-operated series connected guns for spot welding, a notched bar to locate welds, and a control handle to move the gun along. The entire assembly is supported from an I-beam section, above which is located the welding transformer.

Meetings and Expositions

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, annual meeting. New York, N. Y. Feb. 9-12, 1942.
AMERICAN SOCIETY FOR TESTING MATERIALS, spring meeting. Cleveland, Ohio. Mar. 2-6, 1942.
AMERICAN SOCIETY OF MECHANICAL ENGINEERS, spring meeting. Houston, Tex. Mar. 23-25, 1942.
ELECTROCHEMICAL SOCIETY, spring meeting. Nashville, Tenn. Apr. 15-18, 1942.
NATIONAL PETROLEUM ASSOCIATION, semi-annual meeting. Cleveland, Ohio. Apr. 16-17, 1942.
AMERICAN CERAMIC SOCIETY. Cincinnati, Ohio. Apr. 19-25, 1942.
AMERICAN FOUNDRYMEN'S ASSOCIATION, annual convention. Cleveland, Ohio. Apr. 20-24, 1942.

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IN METALLURGICAL SPECIMEN PREPARATION

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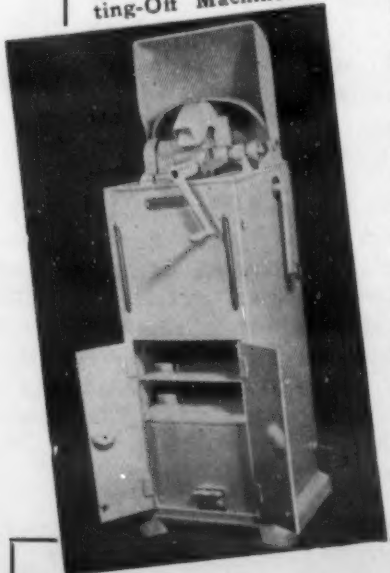
No substitute for consistent results is ever necessary when metallurgical specimens are prepared by the Jarrett method . . . Exact multiple specimen uniformity is assured by the "Grind-Polish" action of special stone laps used in the Jarrett Polishing Machine. Operating technique of the machine itself is so simple that inexperienced operators can produce large quantities of perfectly standardized, high quality specimens in a few minutes.

The Jarrett Cutting-Off Machine. ●



The Jarrett Technique of preparing Metallurgical Specimens consists of these three brief steps:

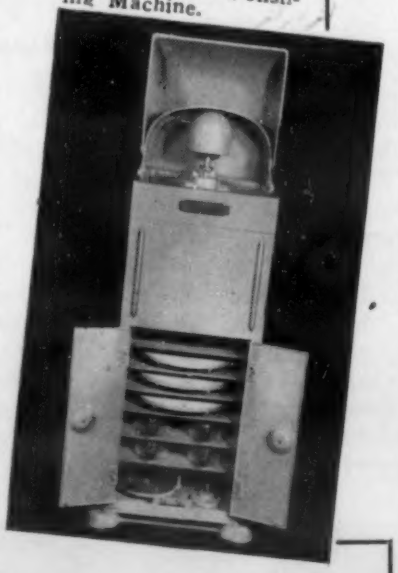
1. Proper cutting of the specimen so that further preparation prior to mounting is eliminated.

2. The freshly cut specimen is mounted in Bakelite or in one of the new prepared mounting rings—further preparation for polishing is unnecessary.

3. Specimen is ground and polished simultaneously using the standard technique established for the machine.

Write for the full details!

● The Jarrett Polishing Machine.



TRACY C. JARRETT
P. O. Box 3155 . . . . Catonsville, Md.

Abrasive Blast Nozzles

An extremely hard, abrasion-resisting ceramic is now being used for the inserts of abrasive blast nozzles manufactured by *American Foundry Equipment Co.,* Mishawaka, Ind.

Known as "Heanium," this ceramic has been developed as the result of years of research, and is claimed to have a hardness and density that is superior to many metals now being used for this purpose.

The jacket enclosing the insert is made of abrasion-resisting alloy steel. The nozzle has a high finish bore, and since the original orifice is preserved without appreciable wear, the contour of the blast stream is maintained.

● A new metal alloy known as "Galvalloy" has become available from *Metalloy Co.,* Los Angeles. With this material it is said to be possible to obtain a perfect soldering bond with aluminum, or aluminum alloy, without the use of any flux. It can be used in foundries for the repair of blow holes or defects, in automobile repair shops for repairing fuel tanks, etc., and as a protective coating on welded seams.

Carbide Tool Grinder

A new carbide tool grinder, available for either wet or dry grinding, has been announced by *Hammond Machinery Builders, Inc.,* Kalamazoo, Mich. The tables are mechanically controlled, and angular settings of each table can be obtained by a hand wheel graduated to degrees.

A crank handle moves the table in or out from the wheel, and uniform distance between the operator and the wheel face is maintained by the coordinated movement of the wheel hood and sludge pan with the table. The table surface is grooved to facilitate tool movement and to help keep the table clean.

Slants and Plants

Timken Roller Bearing Co., Canton, Ohio, was recently confronted with the problem of speeding up production of 3¼-in. to 10-in. O.D. bearings for tanks and trucks. The machines capable of handling these sizes were working at full capacity while at the same time drastic curtailment of passenger car production had thrown 40 of the smaller automatic machines out of production. Timken engineers converted the smaller machines for war production work by retooling them to accommodate sizes up to 8 in. in diameter.

Allegheny Ludlum Steel Corp., Pittsburgh, recently instituted a new scrap and salvage department whose function it will be to handle all scrap for re-melting and to carry out a thorough conservation program to eliminate waste and save strategic metals and alloys.

The United States Navy Dept. will spend nearly $20,000,000 for additional facilities and plants at *Lukens Steel Co.,* Coatesville, Pa., and its subsidiary, *By-Products Steel Corp.* The expansion includes a new flame-cutting plant, additional facilities for handling and shipping rolled armor plate, a new finishing mill, and an armor plate heat-treating plant.

The Seamless Steel Tube Inst., Pittsburgh, has announced the establishment of a new service whereby purchasers may obtain information on the availability of various grades and sizes of seamless steel tubing for new or special wartime requirements.

DURICHLOR Resists Hydrochloric Acid

Like a Duck Sheds Water

Nature provides the duck with the means of repelling water. Nature also provides the elements for making a metallic alloy that repels the deteriorating effects of hydrochloric acid and various chlorine compounds.

Durichlor is this alloy . . . principally of iron, silicon and molybdenum, available in finished cast forms only.

Durichlor is resistant to hydrochloric acid in all concentrations and at all temperatures up to the boiling point.

Durichlor is used not only in the manufacture of hydrochloric acid, but also for handling it in many industries . . . hydrochloric acid pickling; producing and refining petroleum; etc. Also in the manufacture of bleach solutions and various other applications involving chlorine compounds.

A wide range of standard engineered equipment is available . . . centrifugal pumps, valves, pipe and fittings, exhaust fans, mixing jets, tank outlets, ejectors. Special equipment is made in Durichlor to meet special conditions.

As inventors of Durichlor and pioneer manufacturers of corrosion-resistant equipment of all kinds, our specialized experience is invaluable to you. Our engineers and metallurgists will gladly cooperate in determining the proper equipment for your processes.

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DAYTON OHIO

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SILVER may be just the metal we need!

SILVER DATA and RESEARCH . . .

The American Silver Producers' Research Project has for some years carried on a comprehensive research program covering silver and silver alloys for general and specific industrial uses. This research continues today under direction of Handy & Harman who specialize in supplying silver to the arts and industries.

A great deal of valuable data has been accumulated. These data are available to anyone interested in silver and its alloys for industrial application.

The full cooperation and research facilities of the Project are also offered for working out solutions to specific problems.

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Silver is now used in the manufacturing of airplanes, automobiles, ships, tanks, shells, bombs, guns, refrigerators, turbines, electrical appliances, chemical and food handling equipment, surgical instruments, photographic film — to mention only a few. And new uses are developing steadily.

To those who are familiar with the outstanding properties of silver, this is no surprise. Silver excels in ductility and workability — in electrical and thermal conductivity — in immunity to most corrosive agents. Silver, the whitest of metals, has exceptional reflectivity. Silver salts are photo-sensitive. Silver combines readily with other metals, imparting to the resulting alloys a measure of its unique qualities. And not least in importance is Silver's potent germicidal property.

Silver may be just the metal you need — particularly if metal restrictions have created a problem. To help you find out, the Service outlined at the left is available without obligation. We invite you to use it.

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Under Direction of Handy & Harman
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If you need a metal—consider SILVER

METALLURGICAL ENGINEERING shop notes

Bronze Welding Iron Castings

by B. H. Higgs
Linde Air Products Co.

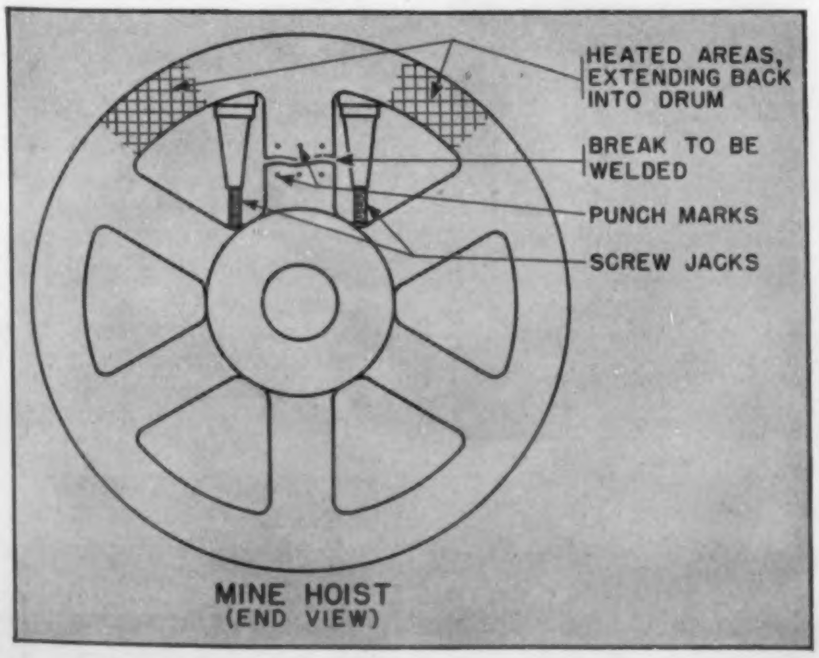
The procedure that was followed in the bronze welding of a cast iron mine hoist drum shows how local preheating can be of assistance for certain types of welding operations where controlled expansion of the part will result in a better weld. The break was located in one of the spokes of the hoist drum. The spokes are in tension during part of the operating cycle and, therefore, a welding procedure that would minimize these stresses and strengthen the weld was needed.

To accomplish this, it was decided to open up the crack by preheating selected areas of the drum's surface, thus causing them to expand and to draw apart the two sections of the broken spoke, and then to fill in the enlarged gap with weld metal so that, when the casting had cooled and contracted, the weld would be slightly in compression. Otherwise, the two sections of the broken spoke would be drawn together slightly during welding, due to the heat of welding, and on cooling would contract, placing the weld in tension.

The accompanying sketch shows how the repair was made. After the edges of the break had been chipped to clean metal, and punch marks had been made on either side to provide a means of checking expansion, the areas (indicated by shading, in the sketch) on the drum flange and the areas behind them, extending several feet onto the drum body, were heated with the welding blowpipe. As these areas expanded, the outer section of the broken spoke was drawn outwards, assisted by the action of screw jacks, as shown in the sketch.

When the opening had increased about 0.05 in., it was bronze welded. The figure 0.05 in. was decided upon by referring to a metals handbook, which gave 0.042 in. as the estimated expansion of a 1-ft. length of cast iron when heated to about 500 deg. F. After welding, the jacks were removed and the preheated sections allowed to cool and compress the weld area. As the weld cooled, it was peened with a hammer.

Standard bronze welding technique, employing a slightly oxidizing flame, was used. The entire operation was carried out without removing the drum from its operating position.



Embrittlement of Spring Clips

by C. E. Homer
Tin Research Institute

Trouble was experienced recently by one concern with the embrittlement of small hardened steel spring clips which had been electrotinned. The problem was referred to the laboratory for study and to find a possible solution.

Experiments showed that embrittlement is produced in the spring clips by pickling in hydrochloric or sulphuric acid, by electrolytic cleaning in acid and alkaline solutions, and by the electrotinning operation itself. Attempts were made to remove the brittleness by annealing, but it was found that 24 hours' treatment at 400 deg. F. was required, as a result of which the coating was completely converted into tin-iron compound.

The possibility of hot-tinning was next investigated, and it was found that the heating of the clips by the molten tin served to a large extent to remove the embrittlement caused by the cleaning. By using a 25 per cent solution of nitric acid for pickling (time required about 30 secs.) and then hot-tinning with the aid of a zinc chloride flux, complete freedom from embrittlement can be secured.

(More Shop Notes on page 278)

Aging of Tools and Gages

by R. B. Seger,
Lindberg Steel Treating Co.

The great demand for tools and gages for comparative and inspection purposes has aroused considerable interest in methods of stabilizing such parts by means of accelerated aging methods. By aging is meant the stabilizing of the metal, so that no further changes in structure will take place after the gage is ground and put into service. This does not mean that the aging process eliminates expansion and contraction of the part with changes in temperature, but it does assure that the part will remain the same size as at that temperature at which it was finished.

As is generally known, a piece of steel if given sufficient time will usually become stabilized of itself. Under some conditions, weeks might be required for the complete stabilization to occur. The result was that methods were long ago devised for quick or accelerated aging. Some of the older methods include such tricks as hanging the steel up and striking it sharply, to mention but one.

One of the most common methods of "season treating," or aging, is as follows: After the gages have been hardened and tempered at about 350 deg. F. for the desired length of time, they are then usually ground within a few thousandths of the required tolerance. (In some cases, the grinding is not done until after the aging treatment.) If much material is to be ground off, it is best to use a very light final grind after aging.

Dry Ice Treatment

To season or age the gages, they are hardened and then heated to about 300 deg. F. in a tempering furnace, and then allowed to cool to room temperature. After cooling, they are packed in dry ice, which, incidentally, will cool them to approximately—105 deg. F. This cycle is repeated four or five times, allowing the gage to come to room temperature each time between the dry ice treatment and the 300 deg. F. tempering furnace treatment. The length of time at which the parts are exposed to the dry ice depends mainly upon the sections involved.

With the very lightest sections, the parts should remain in the dry ice for several hours. Users of the process seem to have no definite rules as to how long the parts should be exposed to the dry ice, but as sections increase in size, the time of exposure is increased accordingly. Four to five hours seems to be an average time of exposure for medium size parts.

The dry ice is packed directly around the parts, and should be packed as uniformly as possible.

The box in which this work can be carried out is relatively simple to construct. The main thing is that it be amply insulated. Several users constructed their boxes with 10 to 12 in. cork all around.

High Carbon-High Chrome Method

Another good procedure to use on gages or parts which must be completely stabilized is to make the part out of a high carbon-high chromium air hardening steel of the analysis of 1.50% C, 12.5 Cr type. After hardening, the steel is tempered at 1000 deg. F. to obtain the secondary hardness of 61-2 Rockwell C. This high temperature draw completely stabilizes the steel.

This method has the very definite advantage that the parts will not change shape on hardening, nor in the draw. Further, the wear resistance of the high carbon-high chromium steel is extremely good. The steel is more expensive, and somewhat more difficult to machine than the more common tool steels. However, these disadvantages are often more than offset by the simplicity of the stabilizing treatment, and the wearability of the gage in service, plus the freedom from shape change in hardening.

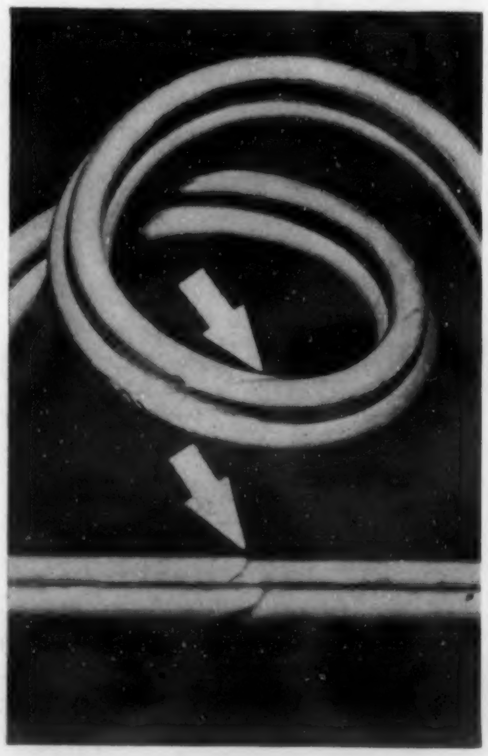
Repairing Copper Cable

by R. T. Jones,
Handy & Harman

In many plants the problem of repairing or extending the length of copper trolley cables is frequently encountered. An effective means whereby the job is speeded up and the metal in the large brass splicers formerly used is saved has been found in the adoption of a low temperature silver alloy brazing method.

When an extension or repair of the cable is to be made, the two ends of the cable being joined are cut diagonally with a hack saw (see the illustration). The two pieces are then butted together and held firmly in place with a suitable jig. The surfaces to be joined are brushed with a low temperature brazing flux which is active at 1100 deg. F.

Heating is done by an oxyacetylene torch, which brings the joint up to brazing temperature rapidly. A silver brazing alloy, flowing at 1175 deg. F., is touched to the heated parts as soon as they show a dull cherry red heat, and penetrates instantly throughout the joint. This operation takes only 5 min. and provides a connection that, electrically, is as efficient as a continuous cable.



The strength of the braze also is as high or higher than that of the solid cable. As a joint of this type is free from internal oxidation, the need for cleaning or other maintenance is eliminated. This cable joining method saves time and improves joint quality. Its effectiveness may also suggest other metal joining operations.

> *There are lots of smart, practical ideas which you have found in your work to be time- and trouble-savers. Why not pass them along to the M & A's* Shop Notes *department, where they will be read with interest by your fellow engineers? And don't forget, we pay for all original* Shop Notes *published.*

The use of concentrated suspensions of graphite in oil (frequently referred to as "oildag") instead of white lead has been found to reduce materially wear of lathe centers. Under operating conditions of heat, and friction, the colloidal graphite, which is the basis of this lubricant, forms a slick graphoid surface on the lathe center. This surface not only has high lubricating values of its own, but also has a greater affinity for oil than the surface metal of the lathe center by itself.

—Acheson Colloids Corp.

Rapid Centigrade-Fahrenheit Conversion

by L. Tulauskas

Many persons have occasion to revert to the use of the somewhat cumbersome formula

$$T_f = 9/5\ T_c + 32$$

to change temperatures expressed in Centrigrade to Fahrenheit when conversion tables are not available. However, few realize that this formula may be manipulated so that the conversion can be made mentally with equal accuracy. This can be done simply by doubling the Centigrade reading, subtracting one-tenth of the product, and adding 32 to the balance. The result is the equivalent Fahrenheit temperature.

Three examples for the well-known temperatures of —40 deg. C., O deg. C. and 100 deg. C. are shown below:

Temp. in deg. C.	—40	0	100
Doubled	—80	0	200
One-tenth of above	—8	0	20
Difference	—72	0	180
Add + 32 to above to obtain			
Temp. in deg. F.	—40	32	212

In many cases the final operation (adding 32) is an unnecessary refinement where the conversion need only be approximate.

For those engineers who are of the mathematical turn of mind (there are a few) and demand proof, the mathematical analysis is given below:

The usual formula is:

$$T_f = 9/5\ T_c + 32 \qquad (1)$$

$9/5\ T_c$ can be written: —

$$9/5\ T_c = 10/5\ T_c - 1/5\ T_c$$

$$\text{or } 9/5\ T_c = (2\ T_c - 2\ T_c/10) \qquad (2)$$

Substituting (2) in (1) we have:

$$T_f = (2\ T_c - 2\ T_c/10) + 32 \qquad (3)$$

which proves the original proposition.

Metallurgical Engineering Digest

FERROUS AND NON-FERROUS

A Digest of
Important Developments
in the World of Metals

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1

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OF METALS, MILL PRODUCTS, CASTINGS

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Salvaging Foundry Waste

"Salvage and Disposal of Foundry Waste." Wm. Y. Buchanan. *Foundry Trade J.*, Vol. 65, Nov. 27, 1941, pp. 343-345, 350. Practical.

The following waste materials are considered:

> *Melting:* Coke and metal from drop; coke breeze and small coke from bins; material from roofs and dust catchers; slag; firebricks.
>
> *Sand plant:* Metal oversize delivery; silt; material recovered by magnetic separation.
>
> *Dressing:* Core sand and molding sand; core wires, grids; dust from grinders, etc.
>
> *Drying plant:* Clinker and ashes from stoves and portable driers; coal ashes from ladle.
>
> *Molding:* Lifters and hangers, etc.; recovery of oil-sand cores.

The material from roofs and cupola dust catchers contains coke, limestone and iron, and probably sand or slag. This material, if left any length of time, rusts together into a hard cake which is difficult to remove from roofs. The quantity of this material produced annually must be considerable, and it is suggested that if removed and placed aside to weather it would gradually form a miniature ore bed that in time would be worth lifting.

Refuse firebricks may be used for concrete or ground and graded for core vent filling, or in some cases wet ground to form loam for special applications. The small metal from molding sand passing a ⅜-in. riddle differs only in size from that recovered from the oversized material, and can be processed and remelted in the same way.

The dust-extraction plant serving the grinders, tumbling barrels, and airless shot-blast machines collects a fair quantity of material that contains a considerable percentage of iron. This material may have some use in its original form—for example, in the making of exothermic powders for oxidation reactions.

The ashes or clinker from stoves and mold driers, if of the hard, clean type, can be used in ash beds, core vent, etc. so long as unburnt coal is carefully excluded. Unburnt coal, such as anthracite used in forced-draft fires, finds its way into sand and causes small gas holes at the mold face.

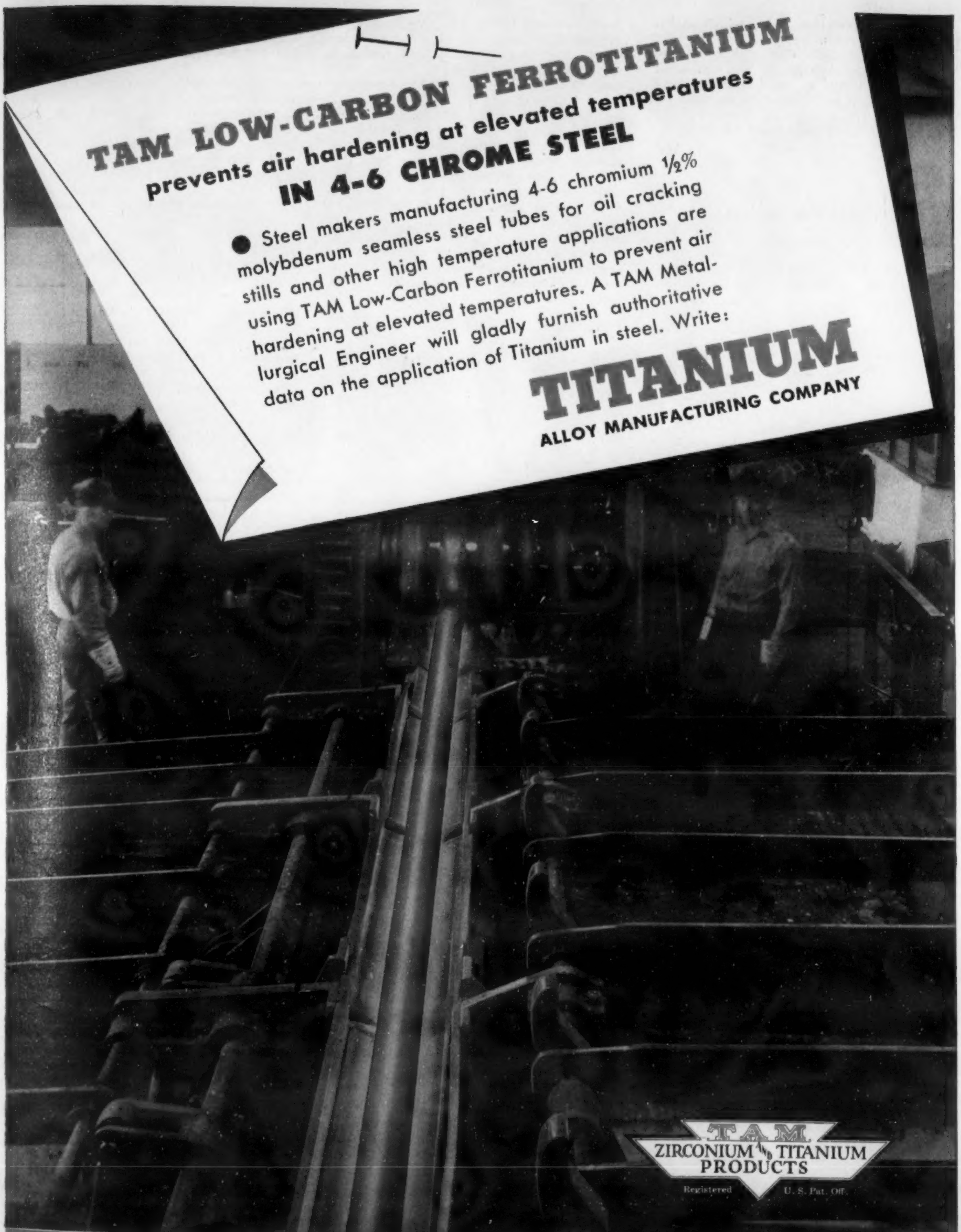
In all large establishments there is a considerable quantity of broken grinding wheels of various types discarded regularly. Those of the silicon carbide type can be utilized in several ways in the foundry, perhaps as refractory bricks in certain positions such as tap holes and similar places. They may also be used as a ladle addition if ground up. AIK (1)

Making Seamless Tubing

"Production of Seamless Tubes by Combined Effects of Cross-Rolling and Guide Disks." W. Trinks. *Trans. Am. Soc. Mech. Engrs.*, Vol. 63, July, 1941, pp. 411-417. Descriptive.

The different processes used for producing seamless tubes are surveyed, and the Diescher elongator method with cross-rolls is described in detail; a theory is developed by which speed of disks, their position and shape can be determined for given cases.

This type of mill is said to produce a tube of better concentricity and greater smoothness. The reasons for this are believed to be a better centering of the mandrel around which the tube blank is rolled, and the greater heat produced by rubbing



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against the elongator disks, which makes easier deformation.

The power consumption is about 95 h.p. per in.^{3} of metal displaced per sec. when elongating to 0.09 in. wall thickness, and about 70 h.p. for elongation to 0.18 in. thickness. The guide disks consume about 25% of the power consumed by the cross-rolls. Ha (1)

Rolling Mill Bearings

A Composite

The quality of rolled metals depends to a surprising extent on the bearings used in the rolling mill and its auxiliary equipment. Smooth-riding, long-lived and easily lubricated bearings aid in the production of uniform-surface-quality and uniform-gage mill products, and are thus a major concern of metallurgical engineers responsible for these properties.

The various types of bearings used on the roll necks—roller bearings, flood-lubricated sleeve bearings, babbitt bearings, plastics, lignum vitae, etc.—have been discussed in these pages before (see, for example, the article on p. 164 of the June, 1939 issue of METALS AND ALLOYS). The bearings on other rolling mill components are also worthy of attention. Recently in *Iron & Steel Engineer* two articles on the application and maintenance of rolling mill bearings appeared. H. E. MCGOFF of Hyatt Bearing Div. ("Application and Maintenance of Steel Mill Table Bearings," *Iron & Steel Engr.*, Vol. 18, Dec., 1941, pp. 46-48) discussed steel mill table bearings.

Prior to 1941, steel mill tables were equipped with brass or babbitt bearings on the table rollers, line shafts and drives. Carnegie Steel Co., in 1941, installed trial roller bearings in one of their 14-in. billet mill roller tables. This application proved successful, and the steel mill equipment builders took up the roller bearing idea for applications in the tables of plate mills, structural and bar mills, blooming mills, slabbing mills, continuous strip mills, and semi-continuous plate mills.

There are two fundamental designs employed today in the application of roller bearings to steel mill tables. The first employs a bearing comprised of an outer race or sleeve and a roller assembly. Alloy steel is used for the table rollers and line shafts with heat treated surfaces, upon which the bearings operate, to provide a shaft hardness equal to the hardness of the outer race of the bearing.

This design renders shaft cutting almost negligible and lends itself particularly well to line shaft applications where several bearings have to be spaced along each section of shaft. However, the heat treatment of these shafts requires very careful attention, and the chances of improper heat treatment are considerable.

The second design, which is being employed in a majority of the later installations, requires a roller bearing comprised of outer and inner races and a roller assembly.

The satisfactory performance of any roller bearing depends upon the accuracy of the application. The shaft diameter and housing bore must be held within the tolerances specified by the bearing manufacturer. For some types of table applications, it is desirable to provide for the alignment of the bearing after the original assembly.

The type of seal required for the protection of roller bearings in steel mill tables depends upon the service the table will be subjected to. Where water and roll scale are encountered, labyrinth seals and some types of felt rings should be used. Air-bound bearings should be avoided for this prevents the lubricant from getting to the rolling surfaces.

After the proper application of the roller bearings, their maintenance becomes a matter of proper lubrication. The lubricant employed should be pure and sufficiently light-bodied under all operating conditions to flow between the rollers and offer no interference to the perfect functioning of the bearing, either at starting or while running.

S. M. WECKSTEIN, of Timken Roller Bearing Co., discussed the use of anti-friction bearings in mill auxiliaries, which must respond to all the variations of speed and load encountered in rolling mills ("Application of Anti-friction Bearings in Mill Auxiliaries," *Ibid.*, pp. 36-39).

Mill screw-downs must respond quickly to changes in roll setting. Tapered roller bearings are used to handle the large thrust loads as well as the radial loads.

The worm shafts, which drive the worm wheels on the mill screws, use two-row steep-angle tapered roller bearings at one end. These bearings are fixed in the worm housing and carry the thrust load in either direction. The two-row bearings at the opposite end of the worm shaft float in the housing and carry radial load only.

On some of the smaller-size mills, the screw-down worm shafts are mounted on single-row bearings. In this design, a

★ ★ ★ ★ ★ ★ ★ ★ ★ ★

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BUREAU OF ORDNANCE
E

"E" stands for teamwork!

"It gives me pleasure to advise you that your organization has been chosen to receive the flag of the Bureau of Ordnance and the Navy 'E' pennant in recognition of your outstanding efforts in the production of ordnance materiel vital to our national defense. Recent events have made this award of even deeper significance than any which have been made in the past."
Secretary of the Navy Frank Knox, in a letter to Monsanto

Among the crews of Uncle Sam's warships and naval planes, the Navy "E" is one of the most coveted and respected honors the men of a single gun turret or an entire battleship can win.

It is a symbol, not of individual brilliance, but of championship teamwork ... teamwork that only long, gruelling hours of actual practice could perfect.

The same tradition governs the award of a Navy "E" to an industrial plant.

The "outstanding jobs" which win an Ordnance Bureau flag and "E" pennant are not the work of one brilliant "lone wolf" in the research department—or a single, capable executive. They are the result of teamwork that only starts with the quarterback in the front office and includes every man in the organization to the policeman on the plant gate ... teamwork that only long years in the peacetime service of industry could perfect to the peak of efficiency demanded by a nation at war!

Monsanto is proud to fly the Navy "E" in recognition of past performance ... glad to accept the responsibility it imposes for future performance. MONSANTO CHEMICAL COMPANY, ST. LOUIS, MISSOURI.

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"JISCO" SILVERY PIG IRON . . .

JISCO FURNACE AND SKIP HOIST

. . . OLD HICKORY . . .

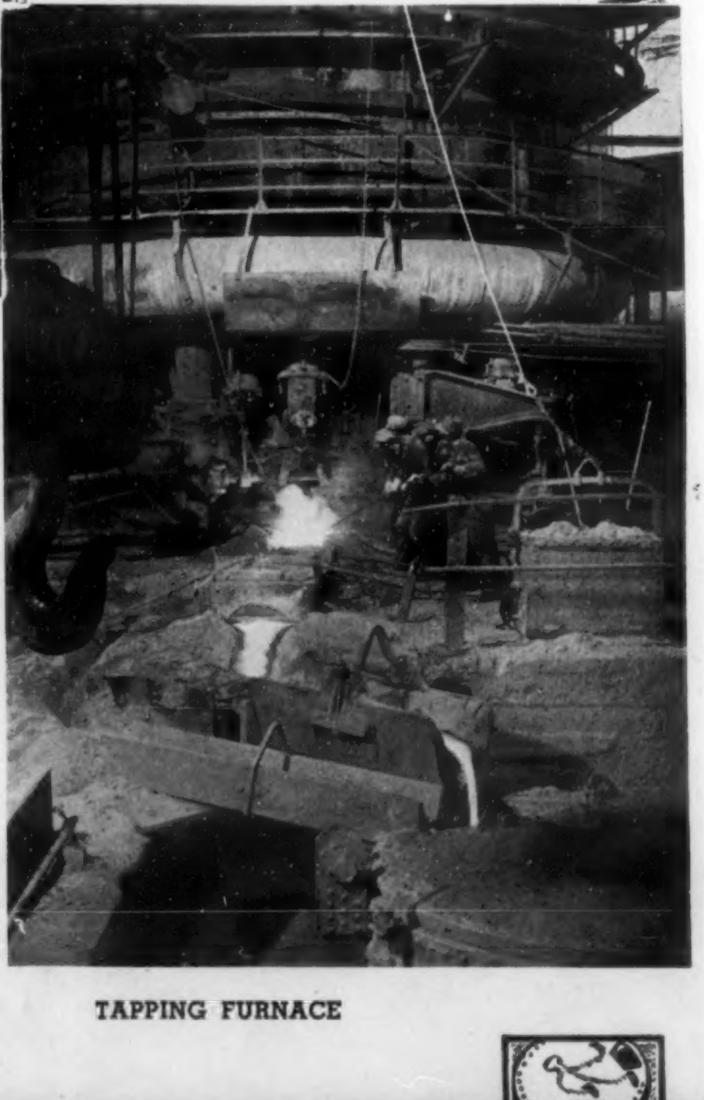
JACKSON DEFENDING DEMOCRACY

'Old Hickory' was always found where the fight was hottest. His leadership was a big factor in young America's struggle for freedom. Today, JISCO Silvery is a big factor in the race to arm for defense.

from skip hoist to ladle . . .

Old charcoal furnaces were built by hillsides in order to facilitate charging. Modern furnaces are filled by skip hoists like the one at JISCO Furnace, pictured above. Efficient charging, larger size, and stronger blast have all contributed to quicker and more complete smelting of iron ores.

In producing silvery iron it requires about 12 hours from the time the ore enters the furnace, until the molten iron is tapped from the hearth. The higher the silicon content of the iron the longer soaking time required in the furnace. JISCO Silvery is mechanically charged, thoroughly smelted, machine cast, and accurately analyzed.



TAPPING FURNACE

THE JACKSON IRON & STEEL *Company*
JACKSON, OHIO.

single-row steep-angle bearing is used at each end of the worm shaft.

Vertical edging mills present a problem of proper pass location, thrust loads and bearing lubrication. All of these points are readily handled by the use of tapered roller bearings. A typical design of a vertical edging mill is as follows: A double bearing mounted in a cartridge is used adjacent to the edging roll and at the bottom of the roll spindle. The lower bearings position the main rolls and the bevel gears and also carry all the thrust loads from the gear and roll.

The drive goes through a coupling at one end of the shaft, which is supported by a two-row tapered roller bearing. At the opposite end of this shaft, a cylindrical roller bearing is used.

The use of anti-friction bearings on manipulators and turn tables is limited primarily to the gear reducers, which are used to drive these units.

A typical single reduction herring-bone gear drive uses double-row tapered roller bearings in all positions. All bearings float except the bearing adjacent to the coupling on the low speed shaft, which is fixed in the housing. A circulating oil system is used on both the gears and bearings.

Guides of various types have been equipped with tapered roller bearings. In the design of a rod mill twist delivery guide, the bearings are mounted directly in the guide roll. The outer races are pressed into the roll while the inner races are mounted with a sliding fit on the stationary pin, which is located in the supports. The bearings are grease-lubricated through a hole in the pin.

A similar design is used on rod mill entry guides. HRC (1)

1a. Ferrous

Open Hearth Pit Refractories

"Casting Pit Refractories." J. H. Chester. *Iron Age*, Vol. 148, Nov. 20, 1941, pp. 43-49; Nov. 27, 1941, pp. 53-58. Practical.

Open hearth ladles are usually of 60-100 ton size. A typical ladle lining arrangement is as follows: (1) 2-in. splits at the back as a safety course; (2) 4.5-in. square built on end; and (3) 6-in. blocks for lining the bottom section. Good shape is essential with ladle brick, since the joints are the weakest part of the lining.

The fireclay brick most used is a siliceous material of relatively low melting point and medium or high alumina content, capable of withstanding temperatures higher than 3000° F. Most encouraging results have been obtained with plumbago brick, made by firing a mixture of about 70% medium alumina clay with 30% of high grade flake graphite. The difficulty here lies in finding a cement that will stand up as well as the brick.

In Europe, considerable use has been made of rammed ladles, the material used being a naturally bonded fine-grained sand known as "klebsand." Advantages of these ladles are: (1) Joints are eliminated; (2) the siliceous batch tends to have positive expansion on firing, which minimizes cracking; and (3) a good glaze can be obtained on the working face.

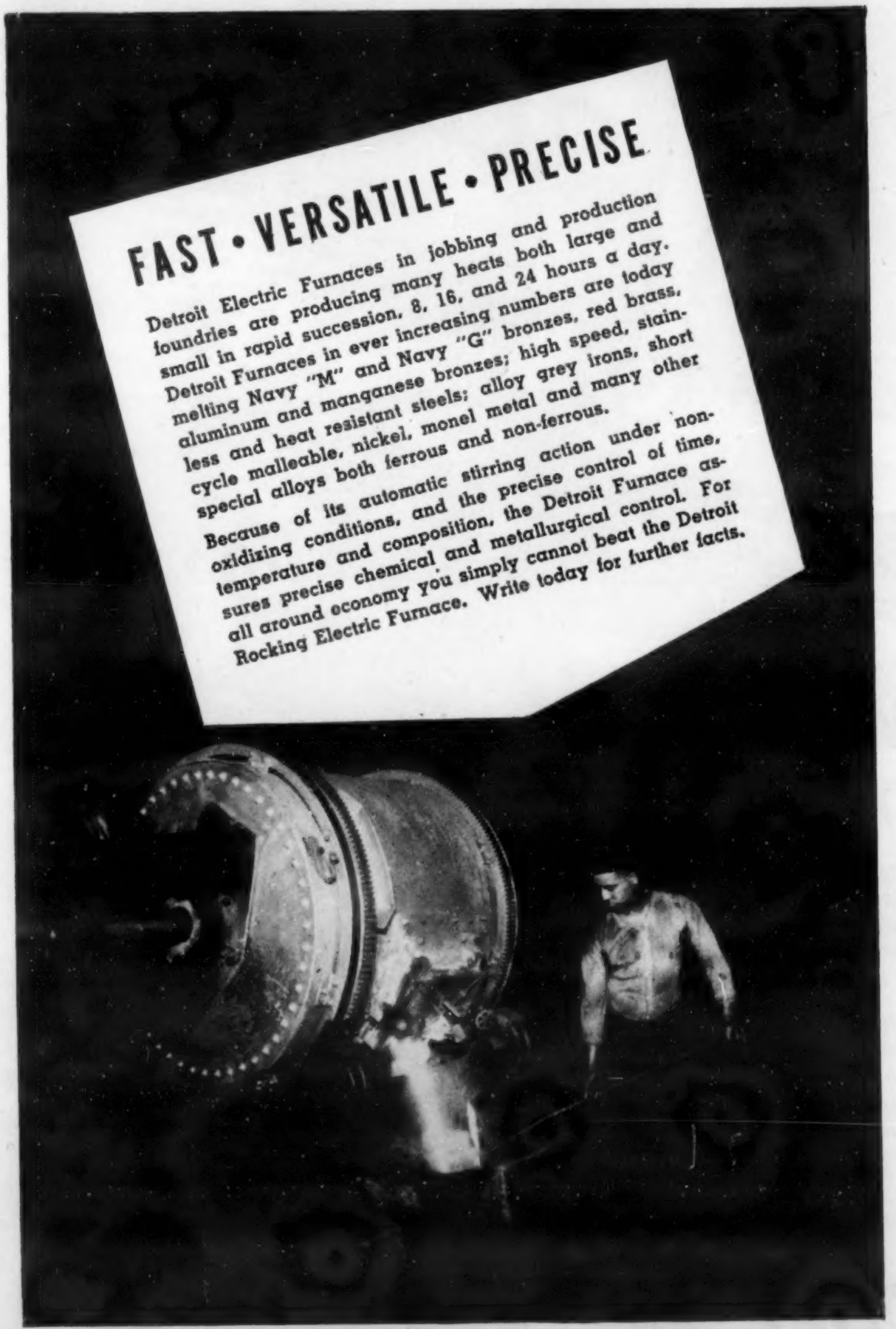
For basic ladles, chrome magnesite bricks have been tried as linings with good results. The use of dolomite brick (either fired or unfired) is more promising. Stabilized dolomite brick tends to have a high spalling tendency and higher conductivity than fireclay brick, which might result in increased skulling, but these may be overcome.

The factors influencing ladle life are: (1) The depth of the slag on the metal in the ladle, varying from 0-3 ft.; (2) the nature of the slag, its basicity and FeO and MnO contents; and (3) the time during which the metal remains in the ladle.

Wear, which is a maximum at the slag metal interface, is due to the slag rather than the metal. Premature failure of ladles may be due to inadequate drying, presence of "black-hearthed" or cored bricks, and to heavy skulls caused by using cold metal or a long casting period. Suggested lines of improvement are: (1) The use of denser fireclay brick of high alumina content; (2) the use of plumbago bricks together with a more resistant cement; and (3) the use of monolithic linings made from basic or stabilised clinker.

The ideal nozzle to use is one that permits teeming the entire cast of steel at a constant speed without splashing and without contaminating the metal. Most British nozzles are made from high-alumina (40% Al_2O_3) clay. The batch is de-aired, and the result is a dense product of low permeability and good thermal shock resistance. The firing temperature is about 2375° F.

The refractoriness of ladle sleeves or rod covers used in America seems inadequate. The thermal shock resistance of rod covers is important since spalling may result. The properties of the stopper set-up need only be such as to insure operation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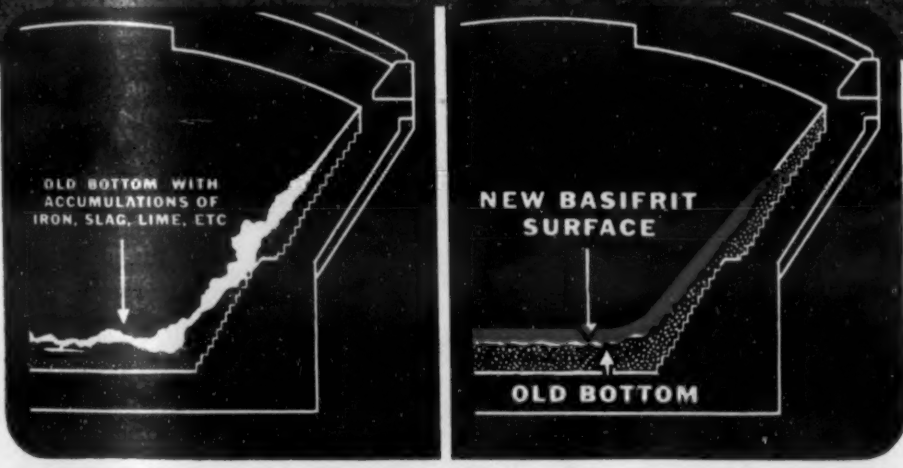

OLD BOTTOM WITH ACCUMULATIONS OF IRON, SLAG, LIME, ETC
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★ Keep your open hearths more steadily on the all-important job of making steel by using Basifrit for deep-hole repairs and for resurfacing.

This fast-setting, prepared magnesite can be installed in less than half the time required for the conventional magnesite-and-slag mixture; in addition, a Basifrit hearth stands up so well in severe service that it greatly reduces delay time for between-heat maintenance.

Proper installation is necessary for best results. Bottom holes should be rabbled clean of slag and metal and filled *quickly* with pure Basifrit, before slag and metal have time to flow back. No admixture of slag is normally needed. In fact, even in new hearth construction only 6% slag should be used with Basifrit.

Sixteen years of successful use by many operators prove the dependability of Basifrit. Now when every minute is more costly than ever before, you can *save time* with Basifrit, and save it *with safety.*

Basic Refractories for the Steel Industry:

MAGNEFER—Dead-burned dolomite for hearth and slag line maintenance.

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BASIFRIT—Quick-setting magnesia refractory for new construction, resurfacing and general maintenance.

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HEARTH PATCH—For deep hole patching and other quick repairs in the basic open hearth.

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during a relatively short time. If trouble arises, say because of protracted holding of the metal in the ladle, duplicate stopper rods and nozzles are often used.

If steel is bottom-poured, then a complex arrangement of guides and runners is required. Runner bricks must be true to shape and size since they fit into a cast iron base plate. They are set dry but the top face is generally covered with cement prior to placing cover plates and ingot molds in position. Bricks having the highest thermal shock resistance were de-aired.

Both in top and bottom pouring, the steel is prevented from chilling rapidly by means of a lining of fireclay bricks or ramming material. The simplest form of liner is a refractory cylinder similar to a guide tube used in small ingots, while the next simplest consist of 4 flat tiles with beveled edges that fit into a square mold.

Often casting pot refractories are blamed for dirtiness of steel, but there is no positive proof. Further work on the subject is certainly required before pit refractories can be blamed for non-metallic inclusions in steel. VSP (1a)

Iron Powder by Hydrogen-Reduction

"Reducing Iron Ore with Hydrogen." M. H. Kalina & T. L. Joseph. *Iron Age,* Vol. 148, Dec. 11, 1941, pp. 39-42. Investigation.

In the treatment of very high grade iron ore or iron compound to produce a powder for use in powder metallurgy processes, complete reduction is necessary. The usual procedure is to follow the course of reduction by analyzing the gas phase.

Studies have shown that porous ores reduce more rapidly than dense ores. Very little work has been done to determine the manner in which reduction of ore progresses from the outside toward the interior.

The present investigation was undertaken to observe the changes in the solid phase. Hydrogen was selected as the reducing agent to avoid carburizing the iron. The rate of flow of gas was 600 cc./min. at 1300° F. Nitrogen was used to establish a neutral atmosphere during cooling.

Limonite of 60% porosity, hematite of 37% porosity and oölitic hematite of 7.4% porosity were used. The reduction time was varied from 25 min. on the most porous material ot 160 min. for the oölitic ore. Small crystal hematite and magnetite were also reduced. Sampling was done by removing concentric layers of partly reduced ore. The specimens were mounted in lucite for microscopic examination.

Partly reduced hematite, from a depth of 0.012 in., showed free iron of 23.8%, ferrous iron 37.3% and ferric iron 6.7%; from depth of 0.425 in., the free iron was 7.1%, ferrous iron 17.5% and ferric iron 33.6%.

Limonite from a depth of 0.012 in. showed 7.5% free iron, 42.0% ferrous iron and 2.14% ferric iron; from a depth of 0.437 in., these values became free iron 3.2%, ferrous iron 23.3% and ferric iron 44.5%.

Oölitic hematite from 0.012 in. gave 16.6% free iron, 22.5% ferrous iron and 12.3% ferric iron; at a depth of 0.425 in., the free iron was 0.40%, ferrous iron 1.0% and ferric iron 43.0%.

Hematite, porosity 7.4%, and reduced for 160 min. showed free iron of 58.5%, ferrous iron 3.3% and ferric iron 2.1% from depth of 0.012 in., while from a depth of 0.425 in. free iron was 0.4%, ferrous iron 3.4% and ferric iron 40.4%.

In reducing particles smaller than 0.001 in. in diam., the particles would be fragments of crystals relatively free from discontinuities. In larger crystals, small included particles and discontinuities afford paths of ready penetration for reducing gas. The reduction in this case starts on the outer grains but discontinuities permit the reducing gas to diffuse into the particle, thus widening the zone of reduction.

In ore with a porosity of 60%, reduction took place throughout the specimen. Rate of reduction in the center was ½ as fast as on the surface. With a porosity of 37%, the center was less thoroughly reduced. In the case of dense Alabama ore, the reaction was confined to a narrow zone 0.04 in. wide. VSP (1a)

Casting Mortar Shells

"Cast Steel Mortar Shells." Edwin Bremer. *Foundry,* Vol. 69, Nov. 1941, pp. 50-55, 124, 126. Practical.

The Auto Specialties Mfg. Co. produces 60-mm. shells for the U. S. Army and 3-in. mortar shells for Great Britain. The steel is melted in electric furnaces by a continuous melting process, using as raw material 30-40% return sprue and gates, and 60-70% low-carbon plate scrap with a small amount of ore.

Heats melt down with 0.16-0.18% C and very low-silicon and are brought to the proper analysis, carbon being picked up from the ferromanganese or by additions of pig iron. About 40-60 min. are re-

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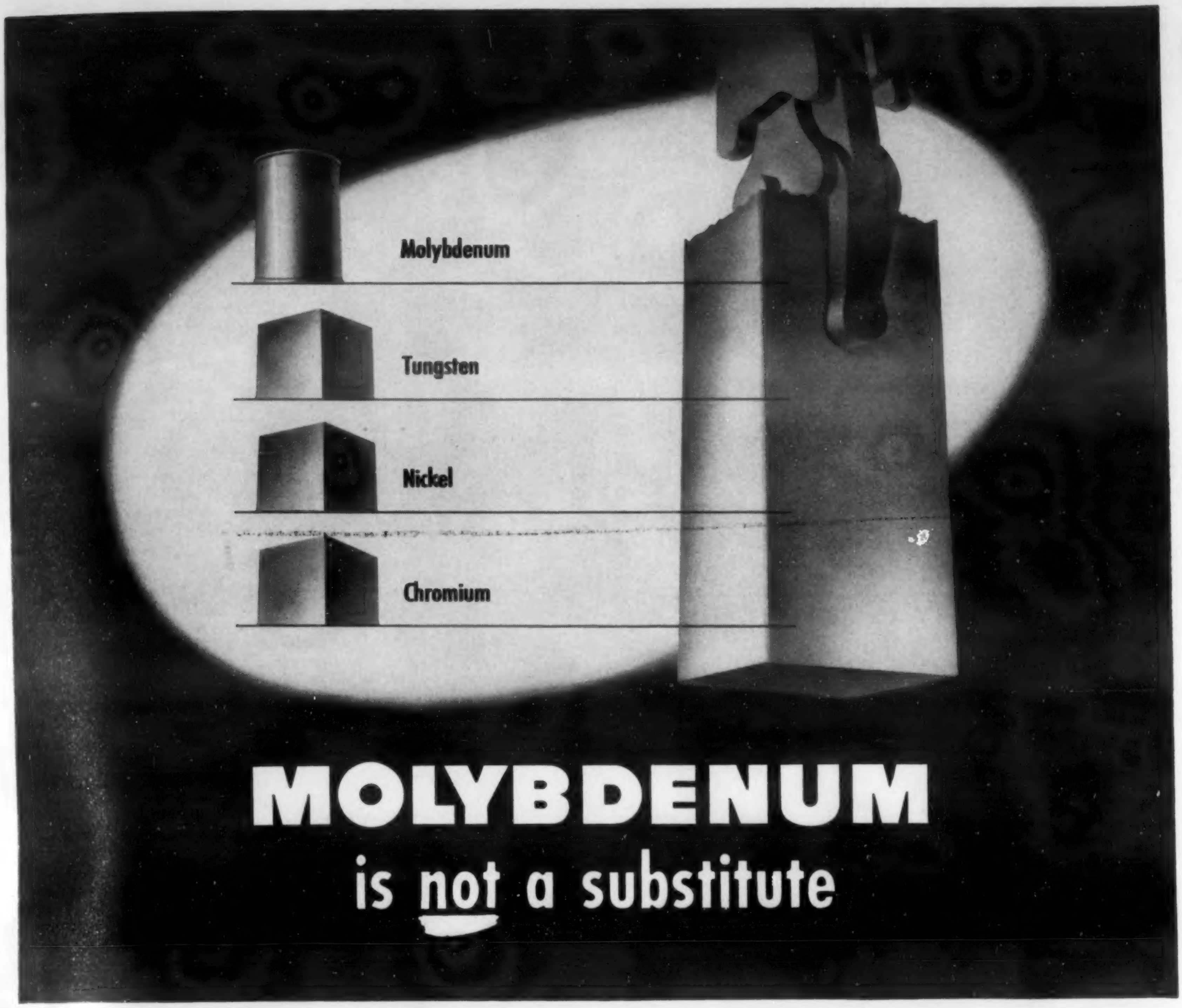

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Molybdenum is not a substitute for any other metal, in the sense that it can be used precisely as they are, with identical results. For tungsten, in that sense, there is no substitute. Nor for chromium. Nor for manganese, or nickel, or any element of sovereign virtue.

Yet Molybdenum and some of these other alloying elements can be employed, each according to its own nature, for many exacting requirements, and physical properties can be developed that give entirely satisfactory performance.

Such a recourse is very important when some of the materials in question become scarce while others are still abundant.

Molybdenum can be obtained for all desired uses. The knowledge of what can be done with it has been greatly extended, and its possibilities go far beyond what had been supposed. New literature is available.

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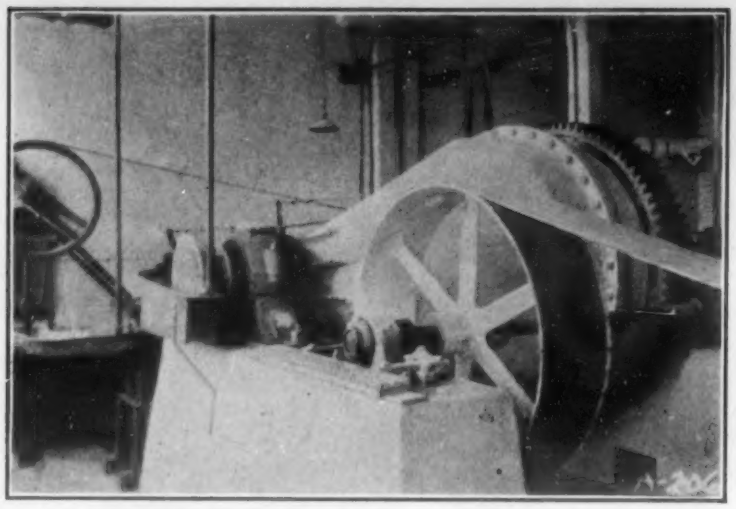

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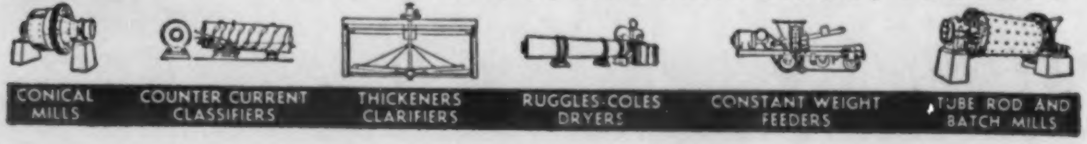

quired to pour off each heat from a small furnace.

The steel is taken off in 350-lb. ladles and poured directly into moving molds. Before pouring, all the slag covering is removed. An optical pyrometer is used for determining temperatures on tapping, which are about 3000° F.; the pouring temperature ranges from 2850° to 2900° F.

The quality of the steel is under careful control. On heats for Army Ordnance shells, 2 keel blocks are poured and from the same ladles a mold is tagged for identification. Shells from these molds are selected for fragmentation tests.

This selection is based on high and low chemical analysis, generally on the carbon content. One keel block is used for determining the physical properties and the other is held until an official O.K. is received from the War Department.

Shell molds are made on a battery of 10 molding machines. The total sand system contains about 100 tons. Drag molds, which are molded and cast in the vertical position, are made on 5 jolt, roll-over, pattern draw molding machines.

The 60-mm. shells are mounted in two rows of 6 or 12 on a plate. The pouring sprue is in the center with the main runner extending between the two rows of shell patterns. Branch gates at right angles to the main runner extend into the casting cavities. About half of the shell casting is in the drag, and half in the cope.

The molds are treated with specially prepared facing sands. The facing of the British shells is comprised of all new silica sand, A.F.A. grain fineness of 48-52, to which 70 lbs. of bentonite is added per 3000 lbs. of sand. The facing sand for American shells is half heap molding and half new silica. Only 20 lbs. of bentonite is added to each 3000-lb. batch. The moisture content ranges from 1.8 to 2.0%.

Heat treating is done in 2 continuous electric ovens with controlled atmospheres. After heat treatment, the shells are cleaned inside and out by abrasive blasting using steel grit. Cores for the British shells are blown on core machines; those for American shells are made by hand.

VSP (1a)

Boron Deoxidizers for Steels

"EFFECTS OF EIGHT COMPLEX DEOXIDIZERS ON SOME 0.40 PER CENT CARBON FORGING STEELS." G. F. COMSTOCK (Titanium Alloy Mfg. Co.) *Metals Technology*, Vol. 9, Jan. 1942, T. P. No. 1417, 13 pp. Investigation.

It has been reported recently (see the article "High Hardenability and Toughness in Carbon and Low Alloy Steels" in METALS AND ALLOYS for June 1940) that the hardenability and toughness of forging steels may be improved appreciably by the use of complex deoxidizers containing titanium, aluminum and vanadium. In the light of these results, an investigation of similar deoxidizers containing various hardening and grain-refining elements was undertaken.

The deoxidizers included 3 manganese-silicon-aluminum-titanium alloys with and without boron and calcium, 3 titanium-aluminum ferroalloys with vanadium, molybdenum and zirconium, respectively, an aluminum-zirconium ferroalloy, and plain ferroboron.

The deoxidizers were used in 3 series of 0.40% C steels, which were melted in a small basic-lined induction furnace and cast in the form of 17-lb. ingots about 2.75 in. square.

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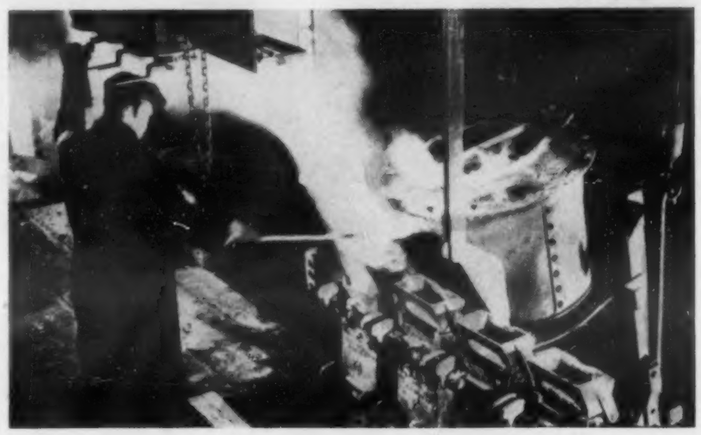

Do you have your copy of "AJAX METELECTRIC PROGRESS" — the magazine of induction melting, electric heat treating, non-ferrous ingot and alloys? Write to: AJAX ELECTRIC FURNACE CORP., 1108 Frankford Avenue, Philadelphia, Pa.

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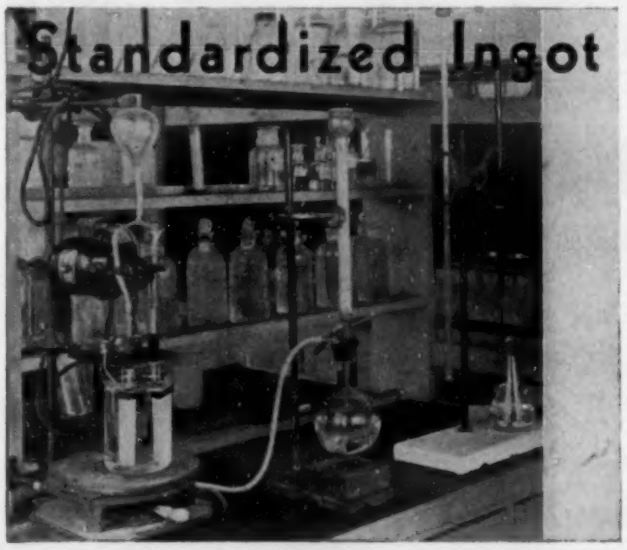

A copper-silicon-zinc alloy of the useful and versatile "Tombasil" family has been developed expressly for the war trend in nonferrous castings.

Its use releases relatively large quantities of tin used in bronze alloys formerly required for such castings.

According to exhaustive laboratory and field reports, this new alloy, known as Ajax **Navy Tombasil**, possesses physical properties far in excess of either Govt. "G" Bronze (88-10-2 and 88-8-4), Spec. 46M6G; or "M" Metal, Spec. 46B8G; as well as the Cu. Si. Alloy known as Spec. 46B28.

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The basic charge for each heat was 10 lbs. Armco iron and 6 lbs. of clean low-carbon sheet-steel scrap. When melted, this charge was deoxidized with 15 grams of ferrosilicon, then about 500 grams of pig iron was added to give the desired carbon content.

After the pig iron was dissolved, nickel shot and high-carbon ferrochromium were added if required, and additions of 80% high-carbon ferromanganese and 50% ferrosilicon were made to provide the proper amounts of those elements.

Aluminum was added to every heat 2 min. after the silicon, for grain-size control and preliminary deoxidation. One minute later, the special deoxidizer was added to the clean bare surface of the molten steel, and 2 min. afterward the steel was poured into the ingot mold, using a hot-top and pipe-preventing compound after pouring to decrease the depth of the shrinkage cavity.

The 3 kinds of steel used for this work were (a) S.A.E. T-1340 (1.8% Mn), (b) 1.15% Mn steel, and (c) S.A.E. 3240 (1.8% Ni and 1% Cr). The carbon contents varied between 0.38 and 0.41%, and the phosphorus and sulphur contents were below 0.04%.

The incorporation of minute amounts of boron (0.002-0.007% B) in fine-grained 0.40% C steels is surprisingly effective in increasing hardenability. The same small boron additions also give good ductility and superior toughness, with high strength after hardening and drawing at low temperatures, such as 450° or 600° F. When drawn at higher temperatures to hardness values below about 45 Rockwell C, the superiority in toughness of steels so treated over steels similarly treated, but without boron, disappears.

To secure a superior combination of strength and ductility, together with high hardenability, in fine-grained steel of this nature, it is advantageous to add the boron in the form of a complex alloy, containing boron, manganese-silicon-titanium, rather than as ferroboron. (1a)

1b. Non-Ferrous

Magnesium by the Hansgirg Process

"MAGNESIUM BY THE HANSGIRG PROCESS." S. D. KIRKPATRICK (Staff) *Chem. & Met. Eng.*, Vol. 48, Sept. 1941, pp. 91-94. Descriptive.

At Permanente, Cal., Henry J. Kaiser has built for the Todd-California Shipbuilding Corp. an [experimental] plant for the production of metallic magnesium by the electrothermic reduction of the oxide—the process of F. J. Hansgirg, who is also personally associated with the American enterprise. [*This is part of the huge expansion program planned by the government, which may eventually boost magnesium production to 400,000,000 lbs. annually, although at present a production of only 200,000,000 lbs. per yr. is in sight.*—H.R.C.]

The Hansgirg process depends, basically, on the reduction of magnesium oxide to magnesium, using finely divided carbon as the reducing agent. The reduction takes place in an electric resistance furnace at approximately 3630°-3810° F. The reaction is: $MgO + C = Mg + CO$. The products of the reaction must be suddenly cooled, since the equation quickly reverses itself. Whereas in the original Hansgirg process rapid chilling was obtained by the use of large quantities of hydrogen, at Permanente natural gas is available for the cooling medium.

FACTS

about

P.B. SILLIMANITE RAMMING MIX

and one man's furnace

FURNACE 500 lb. Moore 'Lectromelt.

SERVICE LIFE 2,275 heats, averaging 753 lbs. of metal per heat. One P. B. SILLIMANITE RAMMING MIX roof outlasted 4 silica side walls.

PRODUCTION 1,710,510 lbs. of metal or 855.25 tons.

PRODUCT Nickel anodes.

ROOF P. B. SILLIMANITE RAMMING MIX power tamped with aid of form, used for monolithic roof. 1200 lbs. required.

POWER CONSUMPTION

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Low	533 KWH per Ton.
Average	553 KWH per Ton.

COST OF ROOF

Cost per heat	3.8c
Cost per ton	10.3c

These are typical operating facts about P.B. SILLIMANITE RAMMING MIX. You can not afford to overlook an operating statement of this kind, if you are using electric melting furnaces of this type, in the smaller sizes—1000 lbs. and under, P.B. SILLIMANITE RAMMING MIX will give you equal economy.

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At the Permanente plant, the magnesia is mixed with petroleum coke to form briquettes and these are fed continuously into the reduction furnace. An atmosphere of hydrogen is maintained in the furnace to prevent the entrance of magnesium powder to the isolated electrode glands.

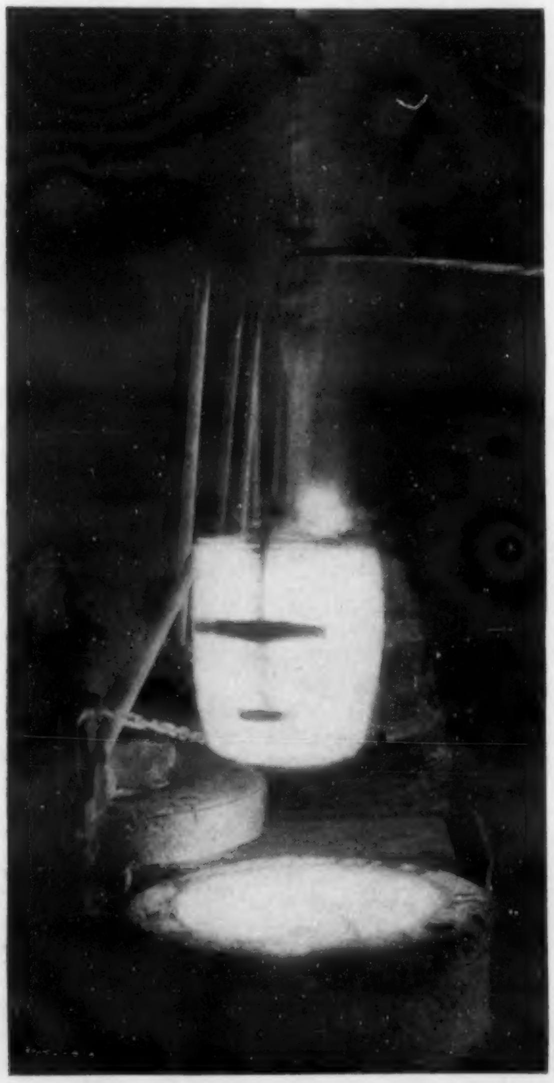
The reaction products are drawn off at one side of the furnace through a specially-designed stainless steel nozzle and condenser. They are immediately chilled by the blast of natural gas. After the initial quenching, the magnesium is carried as fine dust into the cooling chamber, a revolving cylindrical drum. As the velocity is reduced, some magnesium powder drops to the bottom and is taken by a screw conveyor to a dust storage bin.

Meanwhile, the temperature of the gas has been lowered to about 300°-390° F., and most of the dust is carried by the cooling gases to an electric "agglomerator." The balance of the dust is removed in woolen bag filters.

The dust from the primary reduction consists of 60-65% metallic magnesium, contaminated with some magnesium oxide and carbon. It is compressed without a binder into tablets by a specially-designed tabletting machine. The tablets are charged into enclosed, electrically heated retorts that operate at about 1380° F. under an extremely high vacuum. [*Since the product is pyrophoric all this has to be done in a nonoxidizing atmosphere. Use of oil as in the method being studied by the Bureau of Mines could avoid some of these difficulties.* —H.R.C.]

The vaporized metal rises to the upper part of the retort and deposits on the water and oil-cooled steel walls of a removable shell; the shell is later removed to obtain the metallic magnesium, which has condensed into a crystal ring. The metal is taken to the conventional foundry furnaces for remelting and casting into the form of pigs or ingots. The metal in this form is said to have a purity of 99.97%.

Important among the accessory equipment and facilities are: a cooling oil system to remove excess heat from the reduction furnace's electrode glands and the electrostatic agglomerator; facilities for a continuous circulation of cooling water in the jacket around the first cooling chamber and around the top sections of the final retorts; nitrogen for purging apparatus during shutdown periods; and equipment for producing hydrogen by electrolysis of water. (1b)



ENOUGH CRUCIBLES

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9300 crucible furnaces in use melting nonferrous metals.

Keeping them supplied with crucibles is an earnest responsibility.

The crucible manufacturers have added to their capacity and the Government has aided in securing supplies of graphite.

The maximum demand for crucibles will continue to be supplied.

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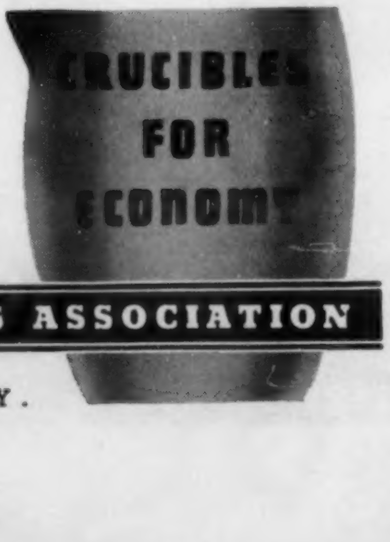
Did you receive copies of the booklet "How to Cut Crucible Costs"? It will help you to get more heats per crucible. Copies may be had by writing to the address below.



CRUCIBLE MANUFACTURERS ASSOCIATION

90 WEST STREET, NEW YORK, N. Y.

Foundry Melting of Brass, Bronze

"Proper Melting Decreases Non-Ferrous Foundry Losses." R. J. Keeley (Ajax Metal Co.) *Foundry,* Vol. 69, Sept. 1941, pp. 56-57, 124-128. Practical.

Actual case histories illustrative of certain simple, practical principles for good non-ferrous melting, with particular attention to bronze and brass castings, are described. The experiences discussed involved natural-draft pit furnaces; open-flame oil-fired furnaces; open-flame and crucible-type gas-fired furnaces, and electric arc and induction furnaces.

In one case, a condition of dirty castings and excessive melting dross was encountered in 88-10-2 alloy made in natural-draft coke-fired furnaces. Excessive oxidation during melting was recognized as the cause, and the trouble was eliminated by *decreasing the area of the flue* (actually by inserting a fire brick in the flue) so as to avoid excessive air, which harmfully extends melting time and causes drossing.

In another instance of dirty castings (83 Cu, 6 Pb, 4 Sn, 7% Zn) and excessive metal loss—also the results of too-slow melting—the condition was corrected by *increasing the gas flow* to the furnace from 1200 ft.^{3}/hr. to 1800. The original volume was much too small for quick (1½-hr.) melting in the 450-lb. open-flame gas-fired tilting furnace used (general practice is to allow 6 ft.^{3} of city gas per lb. of metal melted).

On the other hand, furnaces are sometimes operated with *insufficient air,* as a third instance revealed, and this can also be responsible for slow melting with consequent dirty and porous castings. In the case noted, the faulty performance of a 450-lb. oil-fired tilting furnace was transformed to normal by increasing the size of the air line from the blower to the furnace and by increasing the speed of the blower.

In adding phosphor-copper for deoxidizing, an excessive amount of phosphorus may build up if some allowance is not made for the phosphorus present in the backstock used. Since too much phosphorus may have an adverse effect on machinability, phosphor-copper additions are most safely calculated on the basis of virgin metal in the charge without consideration of the backstop.

Phosphor-copper is the usual alloy recommended to increase the fluidity of nonferrous alloys, but it should be remembered that it *may* excessively harden the metal or cause excessive sand erosion in casting.

The simple expedient of superheating can often be used to overcome porosity in such alloys as 85-5-5-5 for pressure castings. The rapid evolution of zinc vapor (for which an offsetting extra amount of zinc must be added to the charge) is believed to have a de-gassing effect on the metal. FPP (1b)

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Reasons why they should be your choice

1 . . . they're superior in every way to static castings of similar analyses, shape and size.

2 . . . they have the maximum amount of experience back of them, Duraloy being one of the pioneers in centrifugal castings in this country

MANY variations are permissible in centrifugal castings. Straight, true tubing with a wide range in wall thicknesses . . . these are every-day occurrences with us but frequently we produce some rather odd shapes such as illustrated. About the only requirement is that a round hole must pass down through the center.

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Aircraft Welding

A Composite

The tremendous expansion in aircraft production has not only embodied a consequent expansion of welding applications, but has also been aided by the use of welding in many ways. As HOYT pointed out in our January issue (p. 58), arc- and gas-welding of steel tubing and spot welding of aluminum and its alloys are the major uses for welding in the manufacture of airplanes. Recent trends cited by him are a swing away from riveting toward spot welding and a detectable shift to metallic-arc welding away from gas welding.

Gas Welding

Gas welding, though, has its own advantages, and its broad use in the welding of aircraft is outlined by A. K. SEEMANN of Linde Air Products Co. ("Welding in Aircraft Construction and Maintenance," *Am. Welding Soc.*, Paper, Oct., 1941 meeting. Aircraft design has been featured by constant change and, therefore, the building of today's airplanes is still largely a manual job.

Plane design has evolved from the earliest stick-and-wire jobs through the welded steel-tube fuselage to the stress-skin monocoque of riveted aluminum alloy. The airplane of tomorrow may well be large enough to justify the high strength/weight ratio of welded alloy steel in monocoque structures. At present, highly-stressed members of military and commercial craft are welded, with the welded steel fuselage supreme for civilian and training planes.

Uniformly good results in the oxyacetylene welding of heavily loaded primary structures is assured by the adoption of a procedure control for each job—in other words, a written specification that includes (1) initial design for welding, (2) selection and inspection of materials, (3) establishment of correct welding procedure, (4) qualification of operators, and (5) inspection and testing of completed work.

The steel used most commonly in aircraft construction is S.A.E. X-4130, which is air hardening and susceptible to weakness and cracking in or around the joint. Cracks can be prevented by such corrective measures as designing parts specifically for welding, employing an excess-acetylene flame and the correct rod, preheating parts locally, using jigs and holding devices, welding from the center of the seam to its outer limits, and using, in special instances, a "double-welding" technique.

Procedure control should incorporate both the careful establishment of the welding procedure to be used, and qualification of the operators who are to do the work. The welding procedure should be determined after considering both the design and production factors, and then clearly specified.

Operators should be examined for the particular type of weld or welds they will be called upon to perform, and, in order to assure uniformly high-quality welds, occasional destruction tests, made at random, on regular production parts, may prove helpful. Completed welds can be tested by Magnaflux and by visual inspection.

Aside from regular production work, the oxyacetylene process proves valuable for repair and maintenance work in the plant. Typical process applications are the welding of jigs, flame-cutting shapes from sheet and plate, heating parts for bending, flame-hardening and flame-softening equipment parts, and welding pipe for plant systems.

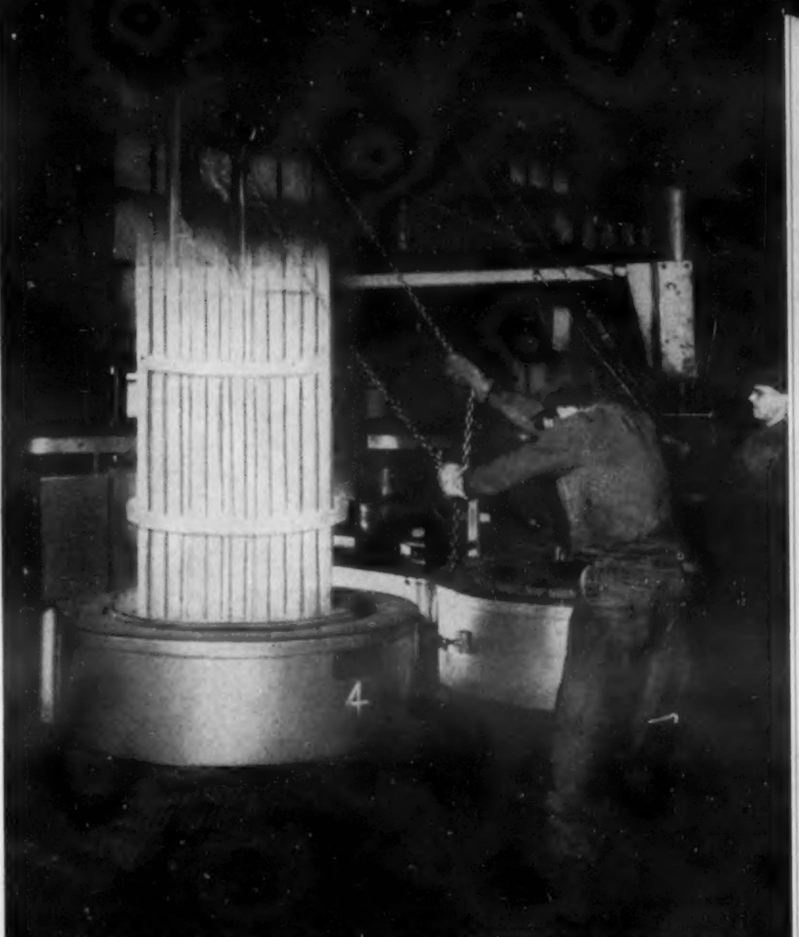
Additional practical pointers on the gas

SOME FIGURES TO USE FOR COMPARISON

A large Wisconsin foundry reports the following production results from their 60″ diameter x 48″ deep Super Cyclone Installation:

HARDENING: Loads for hardening average 2400 lbs.
Heating time averages 1-hour 45 minutes. (Hardening temperature 1600° F. Maximum metal cross section of hardened parts 1¼″)
12-loads handled per day for average daily production of 28,800 lbs. work . . . over 14 tons.
Brinell hardness held within 207 to 241.

NORMALIZING: (using same furnace as above.)
Loads vary between 4500 and 6000 lbs.
Typical load is 5000 lbs.
Time to come to heat averages 2-hour 15-minutes (Heating cycle: heat to 1520°, hold 1-hr. air cool.)
7-heats handled per day average for production of 35,000 lbs. or 17½ tons.



Typical of the loads handled in Super-Cyclones is this 4200 lb. load of 3″ rounds — heated and quenched in less than ⅓rd time required in box furnaces.

STANDARD SIZES IN WHICH THE SUPER CYCLONE IS AVAILABLE

Delivery time is speeded considerably when standard size furnaces are selected, rather than special sizes which must be drawn up. Drawings are available for the following sizes of Super Cyclones all of which have been built and are in operation. Most are gas fired, although a number are available electrically heated.

CHAMBER SIZE	CHAMBER SIZE	CHAMBER SIZE
16″ diameter x 20″ deep	28″ diameter x 28″ deep	38″ diameter x 60″ deep
22″ diameter x 26″ deep	28″ diameter x 48″ deep	43″ diameter x 48″ deep
22″ diameter x 36″ deep	28″ diameter x 60″ deep	48″ diameter x 72″ deep
25″ diameter x 20″ deep	33″ diameter x 36″ deep	60″ diameter x 36″ deep
25″ diameter x 30″ deep	33″ diameter x 48″ deep	60″ diameter x 48″ deep
25″ diameter x 48″ deep	38″ diameter x 36″ deep	60″ diameter x 72″ deep
	38″ diameter x 48″ deep	

100 SUPER-CYCLONE INSTALLATIONS ALREADY IN SERVICE

IMPORTANT NOTE: Like all other Lindberg developments, the Super-Cyclone has been thoroughly proved under 24-hour a day production conditions for a minimum of 12-months before announcement to the trade. Every effort has been made to restrict the sale of these units until the probationary period was completed. In spite of this, however, many of those who have seen the furnace in operation during the past 18-months have quickly been aware of its production possibilities and requested that units be constructed for them. Thus, over 100-Super Cyclone installations are in service from coast to coast. One or more of these is near you, as is a Lindberg District Office, staffed by practical and competent sales engineers. The Super-Cyclone is *not* a cure all, nor do we represent it as such. It is speeding production, turning out straighter work, and cutting costs for many firms however, and we will be glad to survey its possibilities for you, on your work, at your request.

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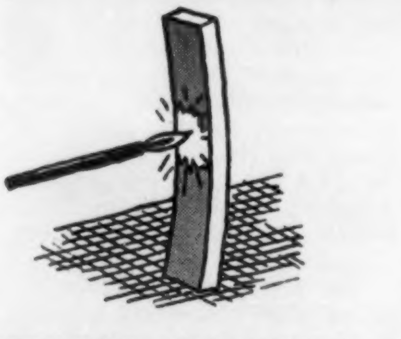
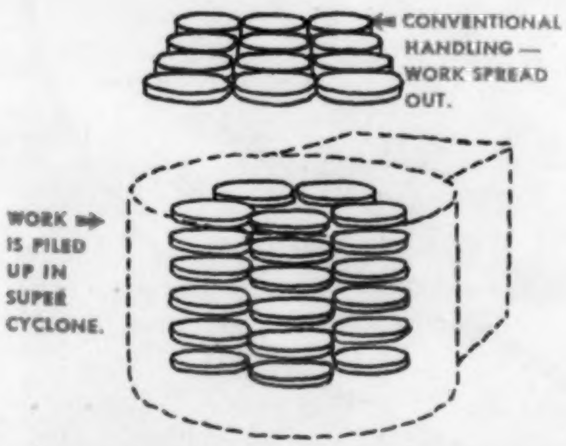
WHAT WILL THE SUPER CYCLONE DO FOR YOU? USE THESE QUICK CHECK TO FIND OUT



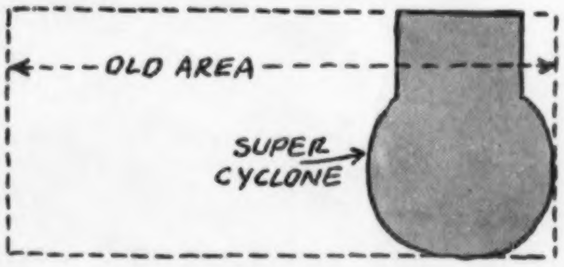
ELIMINATES ONE SIDED HEAT . . . KEEPS WORK STRAIGHT

Prove to yourself how one-sided heat causes distortion. Take a flat bar and heat it on one side with a torch. Notice how it bows. This is what happens when radiation heat strikes only one part of your work in the furnace. Contrast this with the Super-Cyclone in which forced convection is the only heating method. Heat floods through every part of the charge under pressure, and at high velocities. Radiation from a source hotter than the desired temperature is *completely absent.* As a result your work is not strained or pulled out of shape by one-sided heat. The result is that straightening is either completely eliminated—or reduced to a fraction of what is required when work is handled in conventional equipment. When your work goes into the Super Cyclone straight it stays straight . . . cuts straightening costs . . . speeds production.


CONVENTIONAL HANDLING — WORK SPREAD OUT.
WORK IS PILED UP IN SUPER CYCLONE.

HEAVY LOADS ACCURATELY HEATED . . . PRODUCTION SPEEDED

You can easily verify the production increases possible through Super Cyclone Heating. Just spread an average 3000 lb. load of your parts on the floor one layer thick as handled in a radiation heated furnace. Measure the area required. Then take those same parts and *pile them up* in a 36″ or 48″ circle, making allowance for spacers or supports. Figure it will take you a *maximum* of 3-hours to heat the piled up parts on a fixture. Five minutes to quench the lot. Ordinarily you will find production increase of from 200 to 1000% possible. Parts remain on fixture for quenching and tempering, a substantial saving in handling.



CRAMPED FOR FLOOR SPACE . . . THEN DO THIS!

Just measure the total floor space required to turn out your present production by your present methods. *As a very conservative thumb rule you can figure that the Super Cyclone will require not more than ⅓rd the floor area needed by any other type of equipment, to handle the same or greatly increased production.* The result . . . production increases of several hundred percent in present floor area . . . quick production increases without having to move or expand heat treat department area.

These thumb-rules are, of course, general and may not fit all cases. They are averages of what the Super-Cyclone has done in many plants. A Lindberg Representative can quickly and accurately give you any production figures, floor space layouts, or other information you may need.

welding of S.A.E. X-4130 tubing are given by Harold Lawrence ("Gas and Resistance Welding the Aircraft Alloy S.A.E. X-4130," *Steel,* Nov. 17, 1941, pp. 84-85, 88, 90, 100). It is important to assure a smooth, even flow of gases. Special lightweight torches have been developed to permit steady use in all positions, rapid adjustment of flame during welding, and long pointed flames.

"Scale welding" may be used for welding thin-gage metal with minimum distortion. The torch melts the steel and deposits filler metal until a layer has been deposited, and then it is withdrawn slightly to allow the metal to solidify. The torch is again played on the joint with more filler metal being added. This is repeated until the joint has been completed. Protecting gases of flame should be maintained over the metal until it cools to a dull, black heat, and proper allowance must be made for shrinkage.

In any airplane welding work, it is important that welding be done at a speed slow enough to assure melting of the base metal to promote thorough fusion; to preheat the thicker metal, when welding materials of different thickness; to start all welds away from the edge of the joint and weld toward the edge; to keep the joint free from tension; not to begin a weld on a heat treated part of high strength; and to straighten bent parts by heating the convex portion of the bend.

Arc Welding Aircraft Tubing

In an earlier article, Lawrence ("Arc Welding the Aircraft Alloy S.A.E. X-4130," *Steel,* Vol. 109, Nov. 3, 1941, pp. 90, 93-94) discusses the arc welding of X-4130 tubing. Arc welding is being increasingly used for this material, owing largely to new equipment and technique.

Because of the light sections welded, low current values and small electrodes are used. Direct current-processes are used almost entirely. [*Interest in a.c. welding of aircraft is growing, however.*—F.P.P.] Special welding-machines designed for d.c. welding at low amperages with a sufficiently high open circuit voltage are satisfactory. They must possess ample arc stability and capacity for almost instantaneous voltage recovery, and permit the formation of a fine shower of spatter that may be cleaned away easily with hand tools.

Mild steel electrodes of either the general-purpose d.c. or general-purpose a.c. types are used chiefly. The most popular sizes are rods 3/32 in. and smaller. The electrode must have a uniform concentric coating, low spatter level, high arc stability, ability to be strengthened by heat treatment, an easily controlled degree of penetration, and a readily removable slag.

Arc craters in the welding of this steel are a problem that early confronts (and often discourages) engineers who have switched from gas welding to take advantage of the time-saving features of arc welding. Troubles encountered in the formation of gas pockets in the crater can be obviated by employing a "crater eliminator," reports F. R. Kostoch ("Arc Welding of Chrome-Molybdenum Sheet and Tube in the Aircraft Industry," *Welding J.,* Vol. 20, Aug., 1941, pp. 516-519).

With the use of a crater eliminator it is possible to diminish gradually the current and prevent the formation of a puddle of metal in which gas pockets can develop. The crater eliminator consists of a motor-driven rheostat in the generator excitation circuit, and is set into action by the operator by means of a small push-button switch on the electrode holder when approximately ½ in. from the end of the weld. Macrographs show the end of welds without and with the crater eliminator, and are highly convincing as to the entire effectiveness of the eliminator in suppressing blow holes.

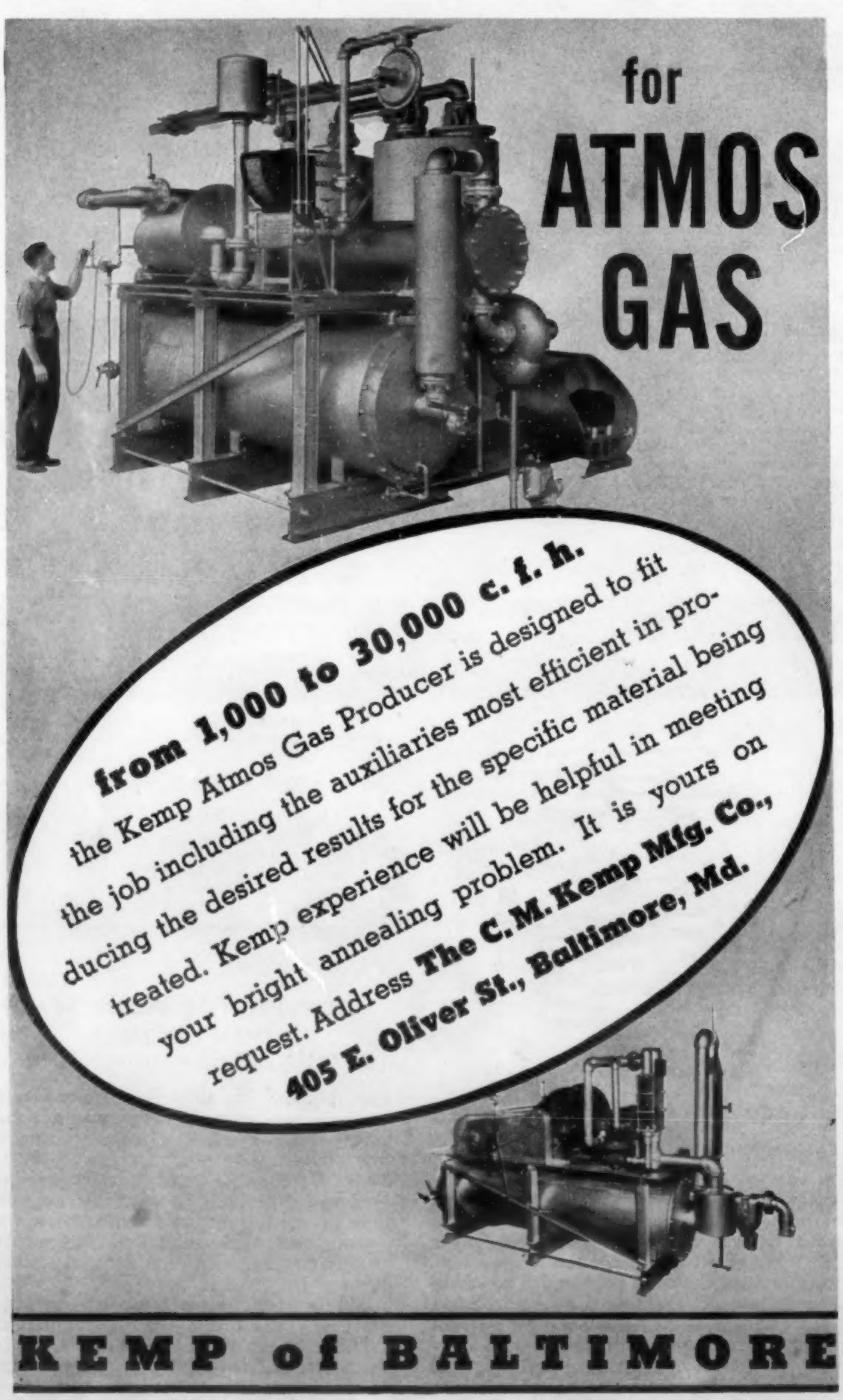
Spot Welding in Aircraft

The rapidly increasing use of spot welding in place of riveting for welding aluminum alloy sheet underlines the importance of the research on the spot welding of aluminum alloys being conducted at Rensselaer under the auspices of the Army Air Corps, the Navy Bureau of Aeronautics, the N.A.C.A. and the Aluminum Co. of America, and with the guidance of the Engineering Foundation's Welding Research Committee.

The first progress report, on 0.040 in. alclad 24ST sheet spot-welded on conventional a.c. equipment, is presented by W. F. Hess, R. A. Wyant & B. L. Averbach ("Progress Report No. 1—Aircraft Spot Welding Research," *Welding J.,* Vol. 20, Sept. 1941, pp. 402S-409S). Electrode tips of 4 different shapes were investigated at several electrode pressures, and observations were made of the effects of time, pressure and current on cracking. The "tentative" conclusions reached are as follows:

The shear strength of spot welds is not a critical function of pressure, current or time. That is, considerable variation in any of the above factors may occur without serious reduction in strength, provided that the combination produces adequate fusion and is such as to avoid cracking.

Cracking can be eliminated by selecting the proper combination of pressure, current and time. In general, an increase in pres-



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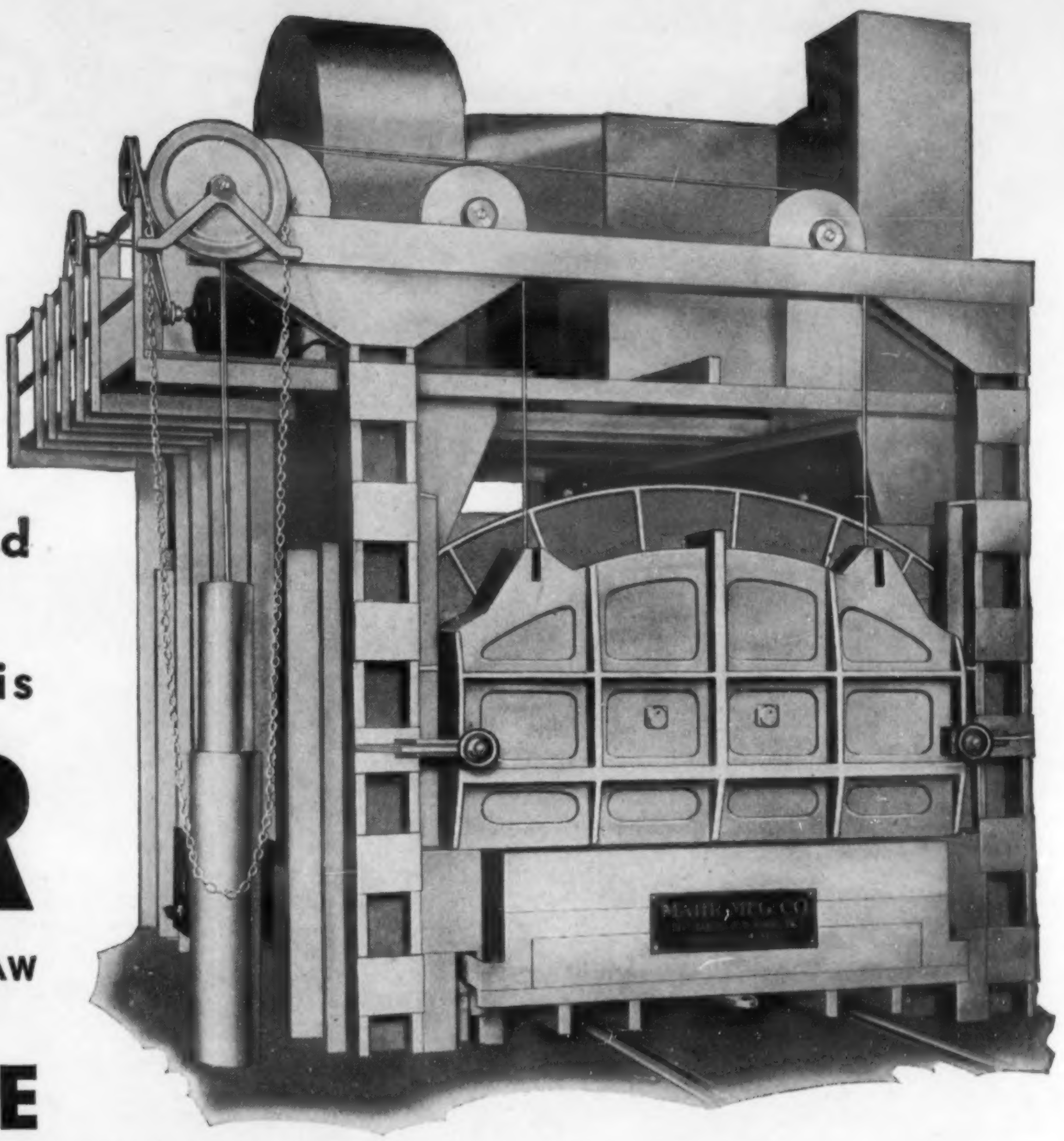

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Distribution ducts in heating chamber are constructed of special refractory design, thus eliminating the necessity of costly alloy and reducing maintenance costs . . . All of the features of MAHR standard car type construction are incorporated in this furnace, assuring the use of a unit with rugged construction, efficient operation and long service-life.

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sure, a longer time or a reduction in current will reduce cracking.

Dome-to-dome electrode tips are preferable to cone-to-cone electrode tips, because sounder welds of higher strength may be produced. The radius of curvature determines the weld strength and the current required.

Sound welds, having a strength high enough to insure a tearing failure, can be made on a machine having considerable friction and inertia. However, excessive friction and inertia render a machine less satisfactory for making welds at low pressures.

For welding at low pressures, it is advantageous to use a special electrode holder for minimizing friction and inertia. Similar behavior could be provided by incorporating low friction and low inertia in the welding machine.

The ultimate quality of a weld is largely dependent upon the conditions attending the fusion during the first 2 cycles of the weld. During this period, significant variations in contact resistance and pressure are found. The variations in contact resistance during this period are a function of the surface treatment. X (2)

Premixing of Combustion Fuel

"Premixed Combustion of Gaseous Fuel for Steel Finishing Operations." E. D. Dunkak (C. M. Kemp Mfg. Co.) *Iron & Steel Engr.*, Vol. 18, Sept. 1941, pp. 69-87. Descriptive.

Premixed combustion is a generic term applied to the burning of gaseous fuels wherein the fuel is prepared for combustion apart from the furnace by admixture with predetermined quantities of combustion air (generally all the air necessary to produce the flame operation in question). The air and gas are then homogeneously premixed and compressed for distribution to the burners.

Premixing has made immersion heating (flame burning in direct contact with a low-temperature solution) practical since by this method alone can the requirements of controlled flame size, rapid combustion, accurate maintenance of air-gas ratio under wide operating range, and high flue gas velocity be obtained.

The economies of immersion heating are: (1) economy of fuel through internal heat application rather than external; (2) close regulation of temperature; and (3) substantial reduction in dross formation in many operations.

The inherent economies of premixing are: (1) central proportioning independent of fumes application; (2) combustion under positive pressure with maximum B.t.u. release; (3) control of air-gas ratio and resultant combustion; and (4) high velocity of flame and products of combustion.

The following problems are suggested for solution in the immediate future: (1) galvanizing through the immersion principle with materials suitable to withstand alloying action; (2) the direct firing of annealing covers utilizing the velocity advantages of premixing to secure both high rates of transfer and uniformity of distribution; and (3) the dilution of high B.t.u. gases for soaking pit firing. CBJ (2)

Metallizing in Aircraft Maintenance

"Metallizing as an Aid to Aircraft Maintenance." Ralph W. Dobbins (Pan American Airways) *Aero Digest*, Vol. 39, Oct. 1941, pp. 337-338. Descriptive.

Although the practice of metallizing cannot be used within the modern aircraft engine on such jobs as undercutting shafts and other wearing surfaces and building them up to size, it has other applications in aircraft engine overhaul.

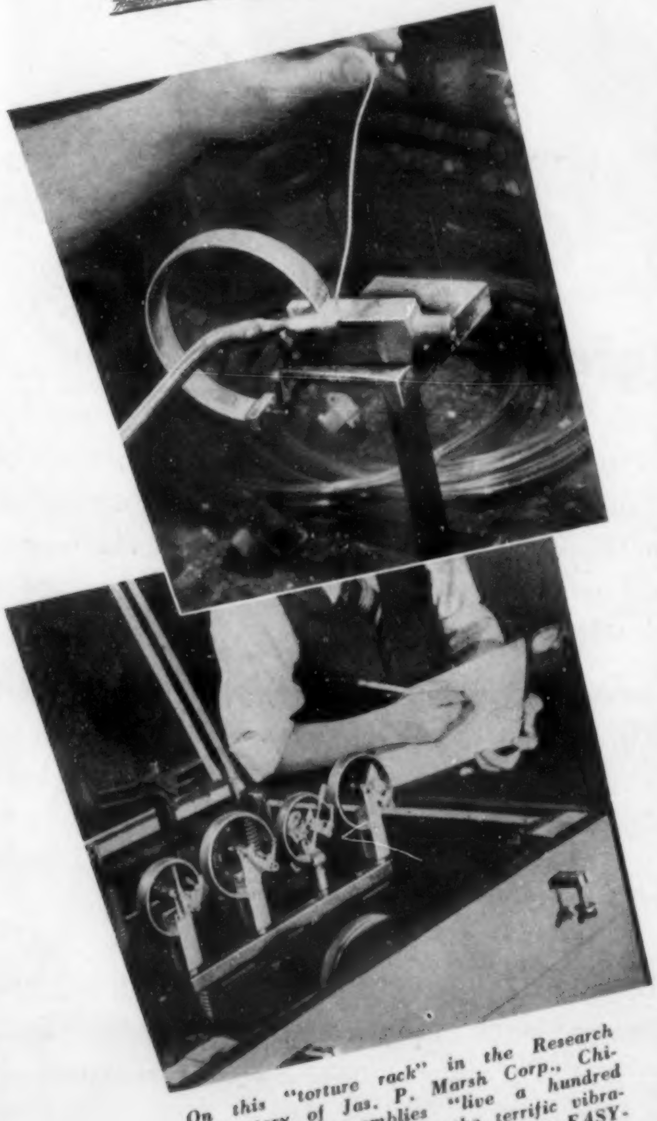
At one time, Pan American's standard practice was to finish the cylinders on seaplanes with baked enamel at each overhaul. It was not uncommon for the paint to become chipped and expose the metal for possible attack by salt water corrosion. This condition was largely the result of high cylinder head temperatures, combined with cylinder expansion. By metallizing, not only was the corrosion problem alleviated but a slightly better cooling of the engines was experienced. The metallized cylinders can be used for two or more overhaul periods without refinishing.

For the metallizing process, the cylinder is first thoroughly cleaned and sand-blasted. The machine parts, studs, etc., and the intake and exhaust valve ports, are protected for the sandblast operation as well as for the metallizing process.

When the cylinders are ready for metallizing, they are placed on a small turntable, which is so constructed as to provide protection for the cylinder skirt and underside of the hold-down flange. Great care is taken in moving the cylinder so that the parts to be metallized are not touched with the hands. Oil or perspiration prevents the sprayed metal from obtaining a good bond.

The intake pipes and push rod tubes are no longer metallized. Metallized surfaces are rather rough and trouble was experienced with leaking at the connections.

Another application of metallizing is in the repair of the main landing gear wheel for the Boeing Stratoliner. The inner bear-



The "Torture Rack" proves the strength and reliability of EASY-FLO brazed joints

On this "torture rack" in the Research Laboratory of Jas. P. Marsh Corp., Chicago, gauge assemblies "live a hundred years in a day". Under the terrific vibration to which this test subjects them, EASY-FLO joints stand up reliably.

THE strength and lasting qualities of EASY-FLO joints have been demonstrated time and time again—but never more conclusively than in the high pressure gauge assembly you see being brazed at the left.

The tubular Bourdon spring is joined at one end to a steel base. This joint must be gas-tight. EASY-FLO brazing alloy consistently makes these gas-tight joints—its low working temperature avoiding damage to the thin spring metal as the brazing is done.

But the manufacturer knows how vital it is for these joints to stay sound under all conditions of service—including abuse. So he subjects the assemblies to tests like that illustrated, which prove beyond doubt that the joints will stand up under conditions far more punishing than any they will meet in actual use.

Of equal importance, EASY-FLO makes these strong, permanently sound joints on a mass production basis at surprisingly low cost per joint.

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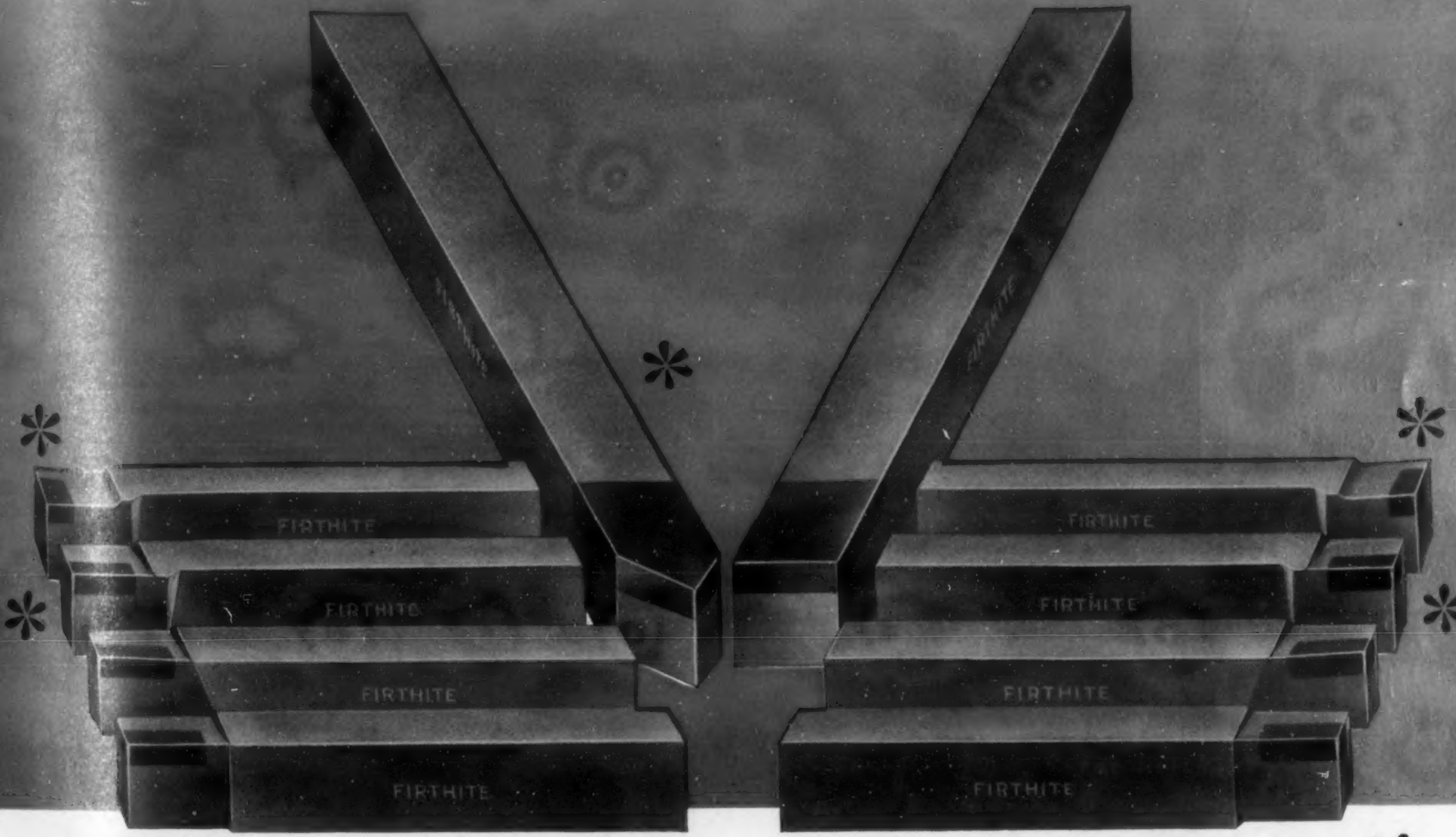
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ing races are subjected to extremely high loads due to landing impact, and have a tendency to become loose in the magnesium wheel hubs.

To repair, the wheel hub is turned out leaving an extremely rough finish. The hub is then amply built up with aluminum metallizing and machined to a smooth finish for a 0.004 in. tight fit. The wheel is left in the lathe and evenly heated, both from the inside and outside, while it rotates, to a temperature of about 175°-200° F. The bearing race can then be easily inserted.

Beaching gear wheels that are installed on seaplanes for handling on land are being continually immersed in salt water, and the problem of corrosion becomes important. It has been found that the use of zinc metallizing in conjunction with regular painting has solved this problem.

Steel fittings secured to aluminum supports are subject to corrosion in the presence of salt water. Metallizing these fittings with aluminum prior to installation and when used in conjunction with zinc chromate primer and grease has considerably reduced the corrosion at these locations. HRC (2)

Diffusion Coatings

"SURFACE TREATMENT BY DIFFUSION." *Light Metals*, Vol. 4, Nov. 1941, pp. 223-225. Review.

The surface treatment of strong aluminum alloys by coating with pure aluminum for corrosion resistance (alclad) is well known and widely used. However, it is sometimes desirable to couple corrosion resistance with surface hardness. The process of surface diffusion (an example of which is the familiar carburizing of steel) offers a broad field of utilization.

In diffusing one metal into another, 3 possibilities (assuming solubility) must be considered: (1) There is complete mutal solubility, (2) 2 terminal solid solutions are formed (alpha + beta); in this case sudden changes in concentration are found at the edge of the cladding metal solid solution, (3) besides terminal solid solutions, intermetallic compounds are formed; here, many layers of different composition may be formed.

Most simply, diffusion of metal A into metal B may be accomplished by heating metal B in a powder of metal A. The presence of a particular phase depends upon the speed of diffusion into the adjacent layer. In general, all the phases of the constitutional diagram will be present if sufficient time is allowed at a suitable temperature level.

In the surface diffusion of magnesium into aluminum, the concentration of magnesium at the surface should not exceed that of the alpha solid solubility limit, or brittleness will result. The formation of brittle intermetallic compounds can be avoided by heating the aluminum in powdered compound Al_3Mg_2. In this way, only that amount of magnesium will be absorbed that is in equilibrium with Al_3Mg_2, *i.e.* the alpha solid solubility limit.

This method can, of course, be used with any other alloy system. *Calorizing* is a well known example of surface treatment, in which aluminum is diffused into ferrous materials by heating them in powdered aluminum. The aluminum-enriched surface is resistant to oxidation and has enhanced corrosion resistance.

Siliconizing is another method that finds application for increasing the corrosion resistance of steels. This process is carried out in the same general manner as described for calorizing, except that in the best-known modification, "Ihrigizing," silicon carbide instead of elemental silicon is used, with an atmosphere rich in chlorine.

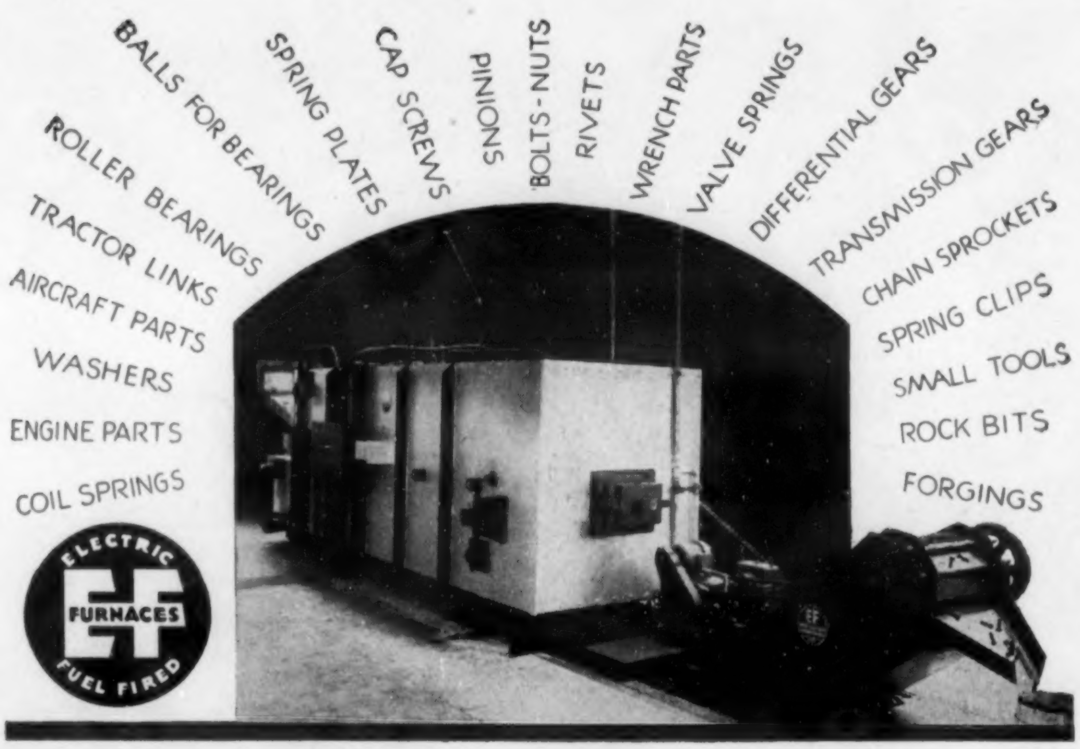
Ihrigized parts cannot be cut with a hack saw, or machined, except by grinding, and they are very resistant to the strong acids, especially nitric. The oxidation resistance is excellent up to 1900° F. and wear resistance is high.

Zinc impregnation is known as *Sherardizing.* The zinc powder should be free from impurities, especially lead, and the process is conducted in the range 660°-800° F.; higher temperatures result in coarsening of the structure. Good corrosion resistance against the atmosphere is obtained.

Diffusion treatment has also been carried out in a salt bath by suspending the diffusing metal in powder form in the salt. Nickel and copper are said to have been surface-hardened by tungsten powder in this way, and aluminum surfaces hardened by magnesium.

In all of the commercial processes described—calorizing, siliconizing, sherardizing, etc.—the possibility of obtaining brittle intermetallic compounds and hence nonadherent and non-ductile coatings is apparent. In some cases, notably siliconizing, this is not serious, and, indeed, to obtain satisfactory corrosion resistance with siliconizing, a comparatively brittle coating is essential.

However, the method previously described of utilizing an intermetallic compound instead of the pure diffusing substance is a possible means of avoiding excessively rich coatings. This method has been used experimentally to diffuse aluminum, tin, bismuth and copper into mag-



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nesium; and silicon, tin, beryllium, antimony and phosphorus into copper.

In some of these diffusion processes, particularly those involving gases, the actual mechanisms involved are not understood. In *chromizing,* a gaseous reaction is used in which chromous or chromic chloride is passed over metallic objects at high temperatures. Metallic chromium or iron-chromium alloys have been used with hydrogen to prevent oxidation of the chromium, and chlorine or hydrochloric acid aid the transfer of chromium atoms to the object. Chromium has also been electroplated on metals and alloys followed by heat treatment to diffuse the chromium into the work.

Beryllium has been diffused into copper from a powdered alloy of copper and 10% Be; the surface hardness rose from 44 Brinell to 82 after 118 hrs. at 1450°-1550° F. An alloy of 9% Be was formed at 0.05 mm. below the surface and one of 0.5% Be at a depth of 0.5 mm.

Similarly, a copper-tin alloy with 23% Sn was used to diffuse tin into copper. As in the case of copper-beryllium, the sample was heated *in vacuo,* but the transfer of tin was accomplished entirely by vapor, as 2 blocks (one of the 23% Sn alloy and one of pure copper) were simply heated side by side. The composition of the original alloy (23% Sn) was chosen so that the solid solubility limit of tin in copper would not be exceeded in the "diffused alloy."

In summary, it may be said that, in general, diffusion coatings as differentiated from electroplated or hot-dipped coatings are used chiefly where some special combination of properties not readily obtained in a solid material are desired. Many diffusion processes are handicapped by the fact that solid diffusion is ordinarily a slow process, and hence likely to be expensive.

AUS (2)

Cutting Tool Performance

"Performance of Cutting Tools." L. J. St. Clair (Gen. Tool & Die Corp.) *Iron & Steel Engineer,* Vol. 18, Dec. 1941, pp. 61-63. Practical.

A cutting tool's ability to cut depends primarily on 3 qualities: room temperature hardness, "red" or operating hardness, and toughness. To use good judgment in choosing a cutting tool for a given job, it is necessary to know the various types of cutting tools and their respective qualities.

Performance Rating of Tool Materials

Type of Tool	*Room Temp. Hardness, Rockwell C*	*Operating Hardness at 1000° F., Rockwell C*	*Respective Standing*		
			Room Temp. Hardness	*Operating Temp. Hardness*	*Toughness*
Diamond tools	Unknown (hardest)	Unknown (hardest)	1st	1st	6th
Carbide tools	72-78	68-72	2nd	2nd	5th
Carbon steel tools	65-67	18-20	3rd	6th	2nd
Cobalt high speed steel tools	64-66	40-48	4th	4th	3rd
18-4-1 high speed steel tools	63-65	35-37	5th	5th	1st
Cobalt, chromium, tungsten cast tools	61-63	54-56	6th	3rd	4th

In the accompanying table (compiled from several tables in the original article) the cutting tools now popularly in use are listed. In the body of the table each type of cutting tool is analyzed with respect to the 3 necessary qualities already mentioned, and then each is given a comparative rating.

In general, toughness is usually the most important quality a cutting tool should have for the great majority of cutting operations. This is absolutely true on heavy work and also true on all tools that require torsional strength, such as end mills, drills, etc.

The next most important quality in most cutting operations is "red" or operating hardness. Room temperature hardness is usually the least important of the 3 when considering general machining operations.

In order to select the right type of tool for a particular machining operation, the job to be machined should be analyzed with respect to: the tensile strength of the material to be cut, and the size of the cut to be taken.

The tensile strength of the material determines the choice of tool in many cases. If the tensile strength is low, toughness in a cutting tool is not required; very little heat is generated, hence "red" hardness is not required. If the tensile strength of the material to be machined is high, a great deal of heat is generated, and a tough tool is required as well as one with high "red" hardness.

The size of the cut being taken will influence the choice of tools. In the case of low-tensile-strength materials, increasing the size of the cut would require a tougher tool where previously, with a thin cut, toughness was not so much a factor.

HRC (2)

2a. Ferrous

More Hints on Heat Treating Molybdenum High Speed Steels

"Molybdenum High Speed Steels." H. J. Stagg. *Can. Metals & Met. Inds.* Vol. 4, Nov. 1941, pp. 296-297. Practical. [*The information in this digest supplements that given in a digest in Jan. 1942 (p. 154), and in the OPM report published in our Oct. 1941 issue (p. 527) and in the feature articles on pp. 457 and 458 of the Oct. 1941 issue.*]

The three general types of molybdenum steel may be classed as: (1) the Emmons type (0.85% C, 1.5 W, 3.75 Cr, 8.75 Mo and 1.10 V); (2) the Kingsbury type (0.85% C, 4.0 Cr, 8.0 Mo and 2.25 V); and (3) the Brealey type (0.83% C, 4.5 W, 4.0 Cr, 4.0 Mo and 1.5 V).

The molybdenum high speed steels can be forged like the tungsten types but at lower forging temperatures, and must be held at these temperatures for the shortest time possible. Large pieces should be preheated at 1000°-1200° F. before bringing them up to the forging temperature.

With long heating cycles, a coating of borax is very effective for the protection of types (1) and (2). No. 3 requires no such protection. The steel hardens from the forging temperature and precaution should be taken to cool the steel slowly to below 200° F., to avoid cracking from forging stress.

The molybdenum high speed steels should be annealed after forging and before hardening or when re-hardening is required. Box annealing with cast-iron

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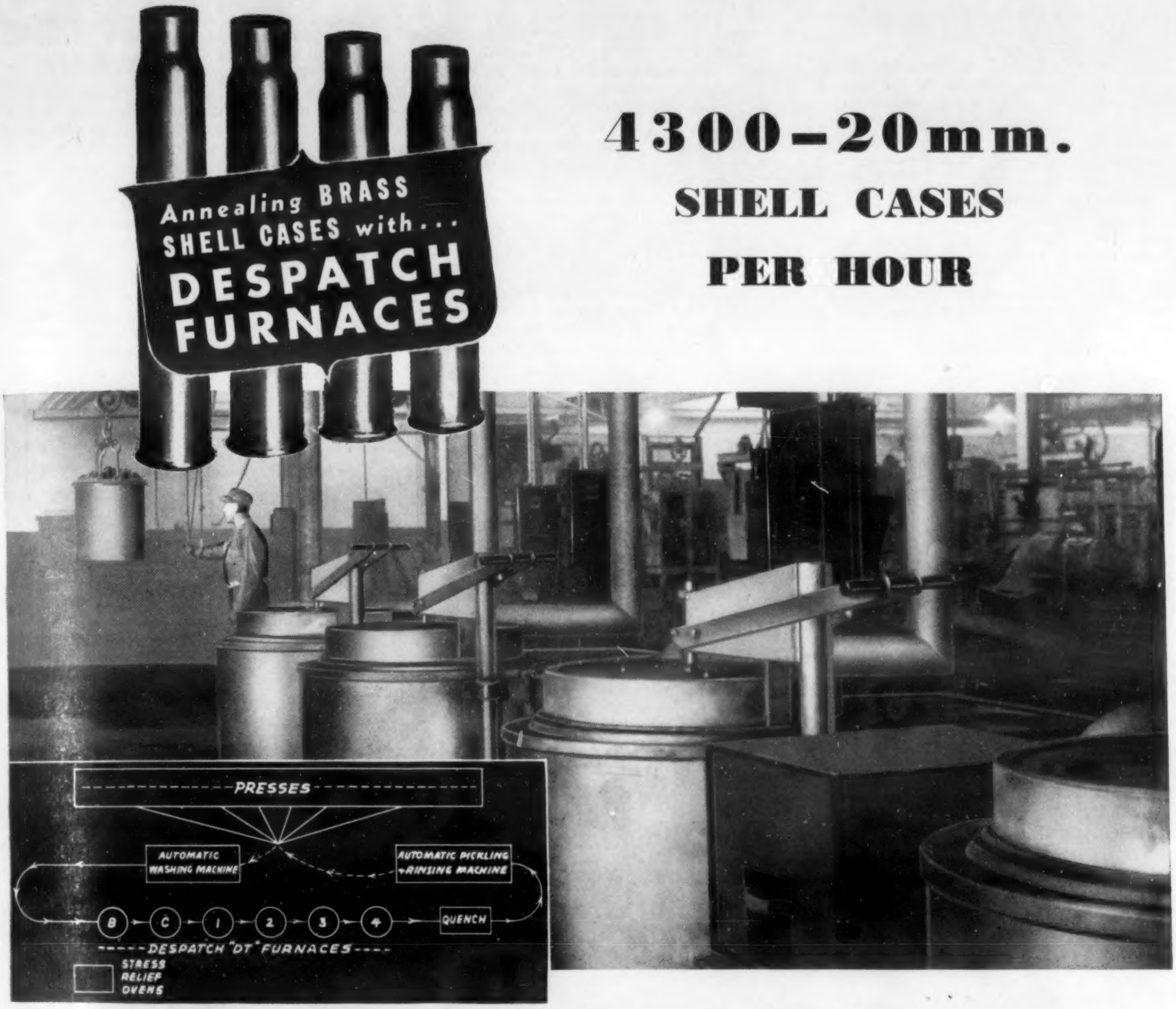

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chips or some other mild source of carbon as a packing material is desirable.

For annealing, the steel should be heated slowly and uniformly to 1450°-1550° F., cooled slowly in the furnace and not removed until it is below 1000° F. After annealing and before hardening the steel should be machined or ground, reducing surface defects and the amount of grinding needed after hardening.

Hardening is effected at 2150°-2275°F., after pretreatment to 1250°-1550° F. The rate of heat transfer is more rapid in salt baths than in controlled furnaces with atmospheres of high carbon monoxide content; salt baths should be operated at 25°-30° F. lower temperature for hardening of this type of steel.

Air, oil-bath, or molten salt baths may be used in quenching, with the latter the preferable medium. The steel should be quenched at 2150°-2275° F. into the molten salt baths, maintained at 1000° F., with the steel left in the bath until it is equalized at a temperature of 1000° F. It may then be air-cooled. An alternative procedure is oil quenching from the hardening temperature to 1000° F., and cooling in air to room temperature.

Tools should be tempered to avoid cracking by re-heating slowly and uniformly from 950°-1100° F., where it is maintained for 1 to 4 hrs. Double tempering is recommended for tools or dies subject to shock.

Single point cutting tools should be hardened at the upper end of the temperature range but when used for intermittent cutting the middle temperature range should be maintained. Cutting tools requiring maximum resistance to shock should be maintained at the lower end of the hardening range.

High tungsten (18-4-1) steels and the three types of molybdenum high speed steels described have substantially the same structural characteristics in the hardened condition. No transformation takes place on cooling from hardening temperatures until a temperature of 300°-500° F. is reached. High speed steel may be hardened by any cooling cycle as long as it is brought below 1300° F. in less than 10 min. At 300°-500° F. the transformation from austenite to martensite begins.

After a single tempering operation, a tool is not completely tempered to martensite and is full of stresses due to expansion. The second temper comes in, for on re-heating and cooling, 100% tempered martensite is secured with a tool in best condition to withstand intermittent cutting.

WHB (2a)

Distortion in Treating Die Steels

"Study of Dimensional and Other Changes in Various Die Steels Due to Heat Treatment." G. M. Butler, Jr. (Allegheny-Ludlum Steel Corp.) *Am. Soc. Metals,* Preprint No. 49, Oct. 1941 meeting, 32 pp. Experimental.

Measurements of length changes undergone by a number of die steels during heat treatment showed that the new air-hardening manganese-chromium-molybdenum steels (3% Mn, 1 Cr, 1 Mo; 2 Mn, 2 Cr, 1 Mo; and 2 Mn, 1 Cr, 1 Mo) could be treated so as to return exactly to their original lengths after drawing. Overheating or prolonged soaking caused shrinkage.

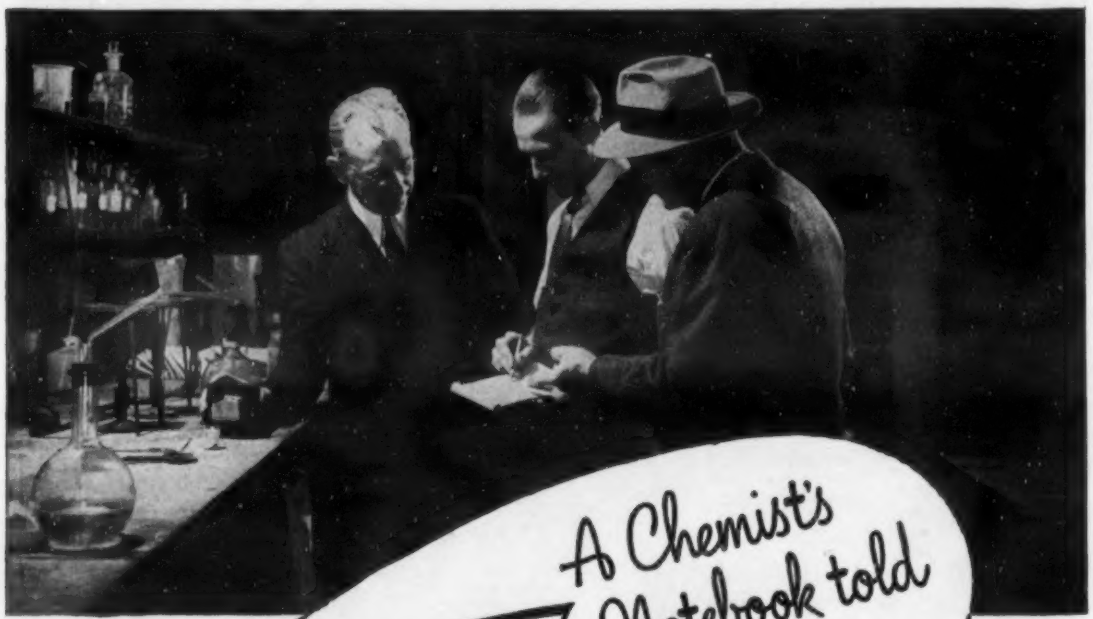
The steel showing the least length change after hardening and shrinkage after tempering was found to be the 3% Mn air-hardening type. When hardened from about 1500° F. this steel showed very little expansion as hardened and practically none as drawn. The 2% Mn, 2 Cr, 1 Mo, and the 2% Mn, 1 Cr, 1 Mo types showed slightly more expansion. But after hardening at temperatures somewhat higher than that necessary for the 3% Mn steel, they returned to their original length as drawn.

Air-hardening high-carbon high-chromium steels showed only slight expansion, while oil-hardening high-carbon high-chromium steels expanded more than any of the other steels studied. Oil-hardening manganese steels expanded considerably on hardening but shrank back almost to initial length after drawing. Steels of the 5% Cr, 1 Mo type showed more expansion than any but the oil-hardening high-carbon high-chromium steels.

Three-dimensional measurements on blocks confirmed the low distortion of an air-hardening manganese steel as compared with an oil-hardening manganese steel and a 5% Cr, 1 Mo steel. Along the grain direction, the latter two steels tended to expand, while the first-mentioned steel shrank.

An intimate relationship was found between length change and amount of retained austenite as measured by magnetic saturation studies. Minimum distortion was shown to correspond to a critical proportion of austenite. In the least-deforming steels this proportion was attained by normal hardening; in the others, undesirable over-heating was necessary for least length change.

Oil-quenching was found to be applicable to certain air-hardening steels but to have no marked advantages. (2a)



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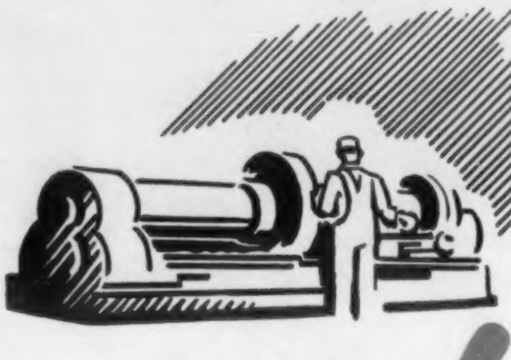

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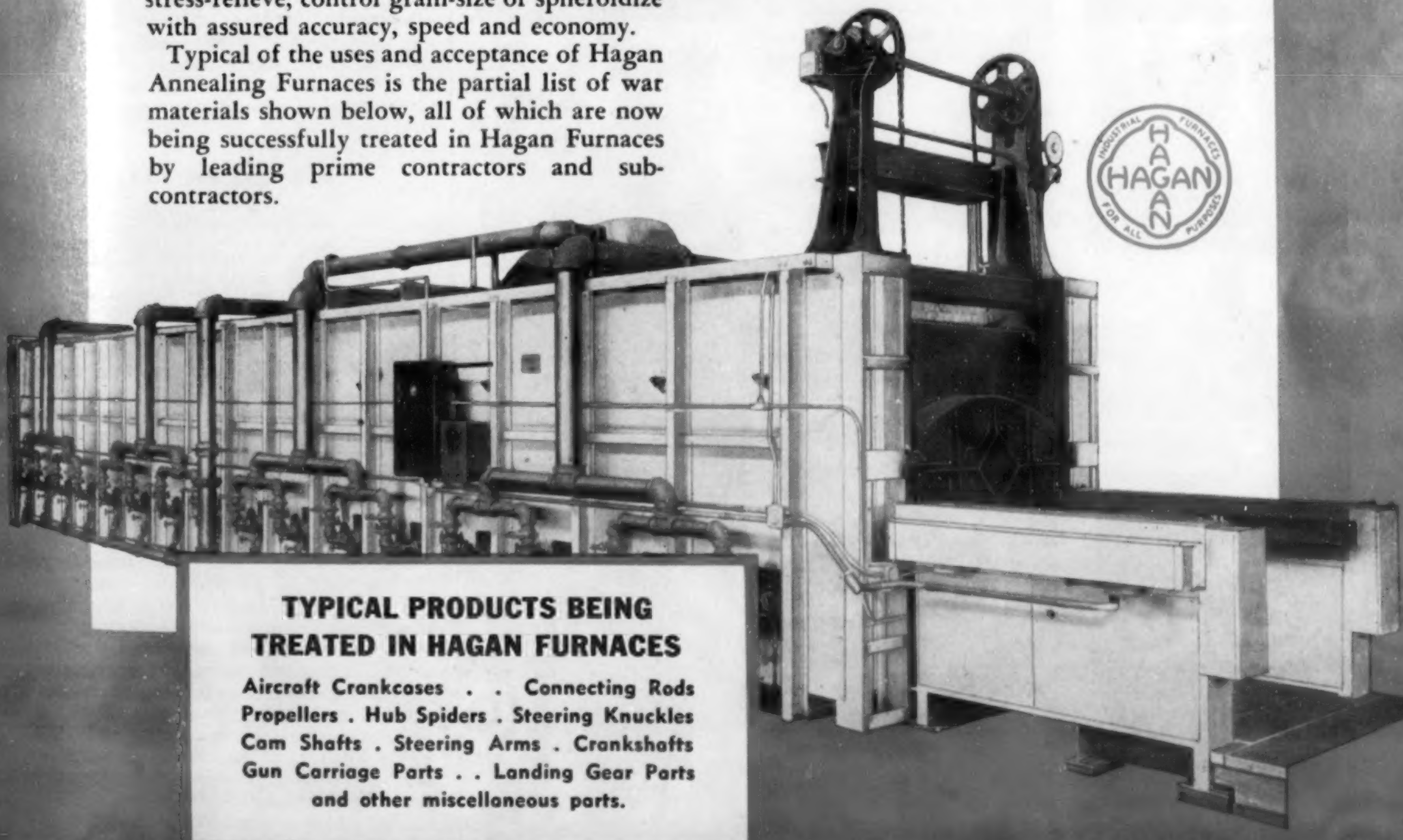

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Embrittlement in Cleaning, Plating

"HYDROGEN EMBRITTLEMENT." H. J. NOBLE (Jacobs Aircraft Engine Co.) *Iron Age,* Vol. 148, Nov. 27, 1941, pp. 46-52. Investigation.

The effects of hydrogen embrittlement as produced by commercial cleaning and plating solutions were studied. Steels subject to a "temper brittleness" range show highest susceptibility to embrittlement at range of 500°-550° F. Of the plates investigated, chromium produced the greatest amount of embrittlement and lead the least.

The problem of embrittlement first arose after cleaning by a proprietary electrolytic process that leaves a tin coating on the work. When cleaned pieces were tested, less than ½ the expected physical-property value was obtained. Embrittlement can be caused by roughening of the work surface, as well as by etching during pickling and by hydrogen absorption. The data obtained with respect to the electro-cleaning process must be caused by hydrogen absorption, because no etching occurs in this process.

In tests, the breaking load of S.A.E. 6150 steel cleaned by the electrolytic process was about 35% of the value for pieces cleaned by sand blasting. Satisfactory heat treatments for relief were 290° F. for 1 hr. and 400° F. for ½ hr.

Elimination of embrittlement produced due to the electrolytic cleaning process may be summed up as follows: (1) Relief can be completely accomplished by proper time and temperature in oil, water or air; (2) air is better than oil, and water is better than air at the same temperature; (3) aging at room temperature relieves embrittlement; and (4) aging at room temperature is more rapid if the tin-plate is removed.

Specimens were prepared for cadmium plating by cleaning in an alkaline bath and pickling in hydrochloric acid. The plate thickness was from 0.0003-0.0005 in. Test results show that the cleaning cycle is probably the principal reason for variation in embrittlement from batch to batch. Aging relieves embrittlement of cadmium plate.

Tests conducted on copper-plated steel before heat treating and on pieces plated but not heat treated, showed that when heated to carburizing temperatures, copper plating produces a more or less permanent embrittlement through the formation of copper-iron alloy. In a test conducted in an electric furnace with no atmosphere control, most of the copper oxidized and flaked off, while in an atmosphere furnace, the copper remained bright.

Tests on S.A.E. flat spring stock showed a wide variation in the embrittling effect of an alkaline cleaner. There was no correlation between the effect and pH values.

From the results, the following conclusions can be drawn: (1) Susceptibility to hydrogen embrittlement in general increases with hardness; (2) maximum embrittlement occurs at the temper brittle range of 500°-550° F., except in steels that are not subject to temper brittle range, such as molybdenum-bearing steels;

(3) Susceptibility increases with hardening constituent, chiefly carbon; (4) hydrogen embrittlement will tend to dissipate on standing at room temperature and can be hastened by heating; (5) complete relief depends upon the embrittling medium or the type and thickness of plate; (6) temperature is a much more potent factor than time in relief treatments;

(7) Hydrogen embrittlement effect increases with decreased section; and (8) embrittlement in steels heat-treated to 40 Rockwell C hardness or under is negligible in most cases. This is restricted to heat-treated steels, since there is evidence that cold-worked material is susceptible to embrittlement at lower hardnesses. VSP (2a)

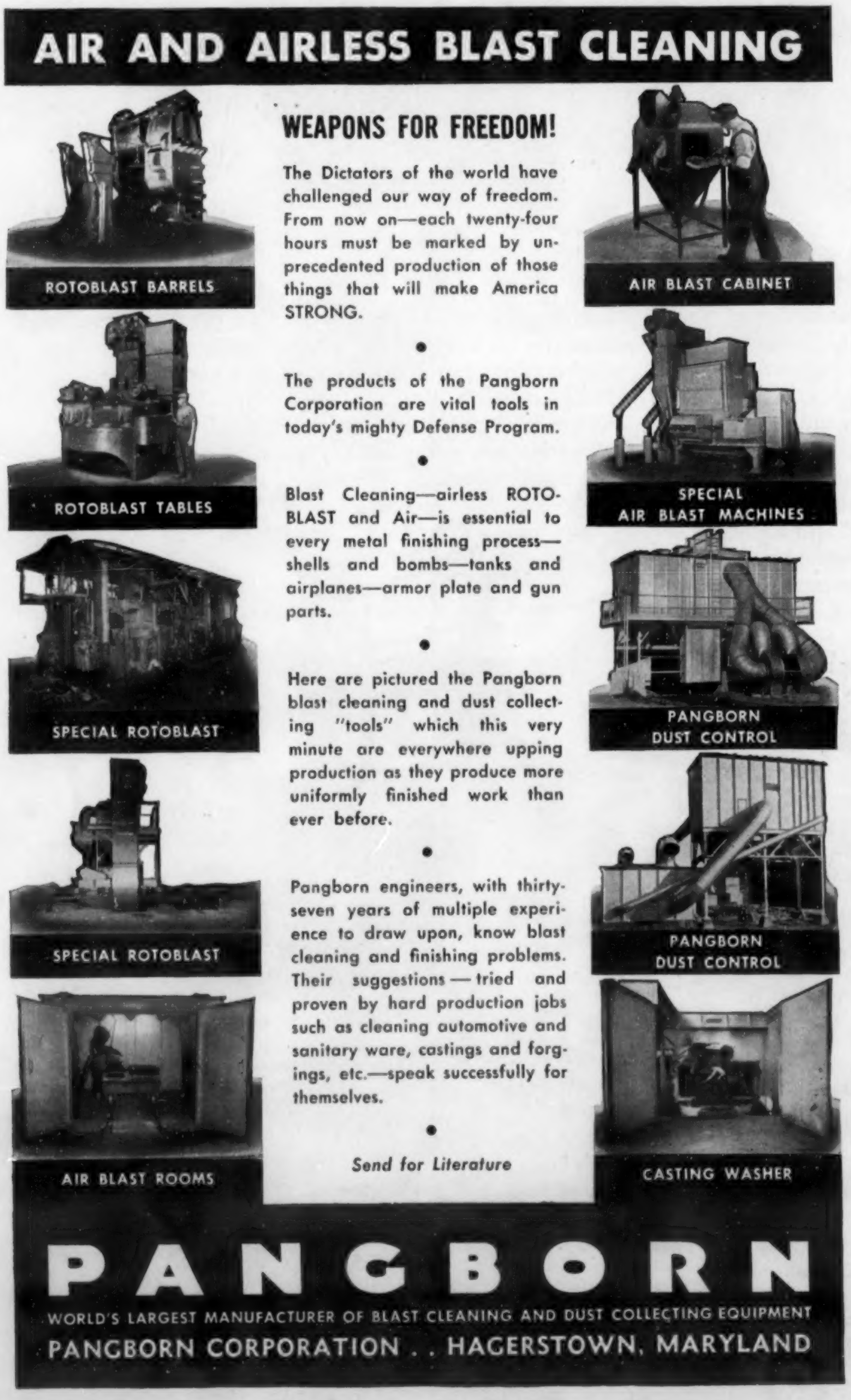
Hydrogen and Flakes

THE INFLUENCE OF HYDROGEN CONTENT, PERMEABILITY AND SOLUBILITY ON FLAKE FORMATION IN STEEL ("Einfluss von Wasserstoffgehalt, durchlässigkeit und löslichkeit auf die Flockenbildung im Stahl") H. BENNEK & G. KLOTZBACH. *Tech. Mitt. Krupp Forschungsber.,* Vol. 4, May 1941, pp. 47-66. Original investigation.

The relations between hydrogen content and flake formation in steel were investigated with specially developed methods of hydrogen and permeability determination. The tests were made with 9 different steels of flake-sensitive chromium-nickel, chromium-nickel-tungsten, chromium, chromium-molybdenum and an austenitic chromium-nickel steel.

All steels were free from flake formation as long as the hydrogen content was below 3.5 cc. hydrogen/100 g. Chromium-nickel and chromium-nickel-tungsten steels showed beginning of flake formation at 6 cc. hydrogen/100 g., and the chromium steel at 3.5; beyond this limit, all steels showed distinct flake formation at 750° F. For temperatures between 750° and 2100° F. no such clear connection between the amount of hydrogen and flake formation could be established.

The occurrence of flakes is connected to a certain minimum of hydrogen, but the absolute amount of hydrogen present depends also on the hydrogen-permeability and on its solubility. If the steel cools slowly



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STRESS RELIEF OVENS!

**Summary of Report from Shell Casing Department,
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Los Angeles, Calif.**

TESTS ON TEMPERATURE DISTRIBUTION—NO LOAD CONDITIONS

Oven controller set at 500 degrees F. Furnace controller set at 580 degrees F. Interior exploration with thermocouples through nine different openings showed no significant difference in temperatures in any of these nine positions!

TESTS UNDER FULL LOAD CONDITIONS—

Seven tests were run in which two thermocouples were inserted in drilled holes in the bases of 105 mm. cases and placed in various positions in the loads.

CONDITIONS OF TEST

Load: Four trucks weighing approximately	800 lbs.
110 cases (105 mm.) on each truck at 6 lbs. each. Total weight cases	2640 lbs.
Oven Controller set for 500 degrees F.	3440 lbs.

Heater Controller set for 580 degrees F.
All bare wire thermocouples used.
Oven up to temperature for varying lengths of time before loading.

RESULTS

These loads of 3440 lbs. come up to 500 degrees F. in 40 minutes. The control couple and the check couple come up to temperature in about the same time — plus or minus three minutes, about the limit of reading the times off the charts.

Check couples in the center of a loaded rack come up in 40 minutes and there is no significant difference in the temperature in any part of the load, in any part of the oven. A temperature difference of 5 degrees usually existed between the two check couples. This difference was not consistent for any location, like front or back, top or bottoms.

The temperature of 525 degrees F. was reached about 15 minutes after the work reached 500 degrees F. and remained constant at 525 degrees F. for about 45 minutes of a one-hour stress relief.

The variation throughout a loaded oven is less than the specified 10 degrees.

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enough, the hydrogen liberated with decreasing temperature can escape and no difficulties arise. But with decreasing temperature, the permeability for hydrogen also decreases, and much quicker in the gamma-range than in the alpha-range. Therefore, gradually increasing time is required for the escape of the liberated hydrogen.

At the point of the gamma-alpha transformation, a large amount of hydrogen is suddenly released due to the discontinuity in the solubility curve, and this can still escape from the steel at sufficiently high temperature. If, however, the gamma-alpha transformation takes place at lower temperatures because of the presence of alloying elements or increased cooling velocity, the permeability is lower and gas pressures may occur that exceed by far the strengtn of the material and lead to flakes. The formation of martensite is not an absolute prerequisite for flake formation as has been formerly assumed, but it does affect the location of the flakes in the piece.

A suitable means for preventing flakes is slow cooling of the steel after hot-deformation. A still better method is to divide the deformation in 2 stages with an intermediate annealing at a temperature just below the transformation point.

This requires comparatively short annealing times, while at lower temperatures longer soaking times are required. At temperatures above about 1300° F., flake formation cannot be suppressed even with longer soaking times.

A method of cooling whereby the gamma-alpha transformation takes place at as high a temperature as possible is, therefore, favorable for the prevention of flakes. This pearlitizing annealing is especially suitable in this respect. MH (2a)

Welding Ships

"REPORT OF SUB-COMMITTEE ON THERMAL STRESSES AND SHRINKAGE IN WELDED SHIP CONSTRUCTION." *Welding J., N. Y.,* Vol. 20, Sept. 1941, pp. 587-591. Survey.

Ship welding has had an extensive service trial over a period of years with a remarkable record of satisfactory performance. Many ships whose construction in whole or in part violated many principles of stress-free welding procedure, have undergone sea tests without failure.

The topic is divided into 3 main subdivisions; (1) Loss of original dimensions, which must be compensated to prevent loss of principal design dimensions. (2) Distortion or loss of shape by warping, twist, with appearance of buckles and wrinkles, or rise of bow or stern. (3) Residual or locked-up stresses, either in the welded joint or in the structure, due to shrinkage in proximity to the welded joint.

The methods of correcting for loss of dimension by shrinkage are discussed; the most common one is to add an arbitrary allowance or excess to the lengths and widths of plate and then to remove this excess when as much shrinkage as possible has taken place.

The removal of distortion especially where localized in the form of buckles in flat or but slightly curved plate is most troublesome and should be prevented (rather than remedied after it has occurred) owing to the great expense of corrective measures. Shipbuilders have experimented with various methods, the principal ones being, (a) pre-springing or initial distortion, (b) strong-backs or jig methods, (c) drum-heading or restraint method, (d) large extent of tacking and wandering sequence to give virtually simultaneous completion of all the welded connections, and (e) design.

Correcting for distortion when it has occurred may involve (a) heating and cooling cycles together with mechanical work to shrink the excess material in the wrinkle or buckle, (b) shrink-welding, where beads of weld metal are placed on convex side of buckled area, (c) added stiffening. The success of these measures depends upon the extent of the shrinkage caused by setting up equal and opposed stresses, thus creating residual stresses in many instances.

Examination of the reports on stress distribution leads to the conclusion that in and near a welded joint it is exceedingly complicated and indeterminate. High residual stresses exist irrespective of any external restraint, but they compose an internal force system, which obviously must be in equilibrium, and they are slowly dissipated or redistributed over a considerable period after welding.

Only where the welds are exposed to sudden changes in temperature such as in winter welding is there a serious possibility of weld failure. Stress relief by heat treatment is therefore considered to be wholly unnecessary in ship welding except for exceptionally heavy welds. Dependance is placed upon the ability of the ductile steel plate to accommodate the stresses.

It is concluded that (1) the phenomenon of shrinkage is complicated by so many factors beyond the control of the shipbuilder that tables of predicted shrinkage

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Army M-3 tank taking steep grade in maneuvers. Photo by Acme.

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are of no value; (2) the detrimental effects of correcting distortion subsequent to the completion of the structure may be as serious as the residual stresses involved in most methods of prevention; (3) residual stresses in ships, incident to joints welded under various and indeterminate degrees of restraint, do not appear to affect the strength of the structure in service provided: (a) The filler metal is deposited by electrodes conforming to Grade E6010 of the filler metal specifications or an equivalent process giving a similar degree of ductility, (b) the structural material is of proved welding quality, and (c) due care and diligence is observed in preventing (or detecting) stress cracks during and immediately following the welding operation.

WB (2a)

2b. Non-Ferrous

Forging Light Alloys

"The Forging of Light Alloys." *Metal Industry,* Vol. 59, Oct. 17, 1941, pp. 242-244. Report of an "open forum" held in England.

According to Chadwick, a number of different types of alloys are used for forging, but the greater part is done on heat treatable aluminum-copper-magnesium alloys. These alloys are either forged from the cast condition or from the extruded condition, preferably the latter, as in that condition they are more ductile and there is less likelihood of surface cracking in the early stages of forging.

Large forgings can, however, be made from the cast alloys. A large proportion of light alloy forgings are of the hot-stamping type, the work being carried out in heated dies with either a crank press or drip hammer or pneumatic hammer.

One of the points that makes light alloy forging not so easy as the forging of some other alloys was that unless the temperature is correctly maintained in the forging process, the strength of the product will be inadequate. Also, rapid forging with too high a velocity gives lower strength forgings than those produced under slower presses. The highest strength is probably produced under hydraulic or other presses working very slowly. It appears that if the structure is deformed too rapidly, it breaks down in the same way as when it is forged too cold.

One new development is the induction heating of parts to be forged. The products can be passed through a small induction heater at a fixed rate and then fed to the press, with assurance of getting them exactly at the temperature required. This method is used more for magnesium than for aluminum alloys.

Stokeld also discussed extruded bar as a raw material for forgings. The extruded bar often contains irregularities that appear as defects in the finished forging. The concentric mass of material has a central portion of fine grain, the outer portion being coarse grained, and this latter is very difficult to use for forgings.

This is an effect of the extrusion process and usually occurs toward the back end of the extruded bar, while the front end is usually clear of it. The large grain material was a nuisance in forging, because if the billets are left too long at the forging temperatures, the large grain effect increases with soaking and, consequently, the large grains tend to disassociate from one another.

Edwards said that blistering in the Duralumin type of alloy is generally caused through overheating of the metal. Propeller shaft forgings made from 6-8-in. bars and squeezed out to shape are a good example. It probably takes from 5 or 6 hrs. from heating the first forging and they will probably be pressing for 5 min.; then they become too cold for further pressing operations.

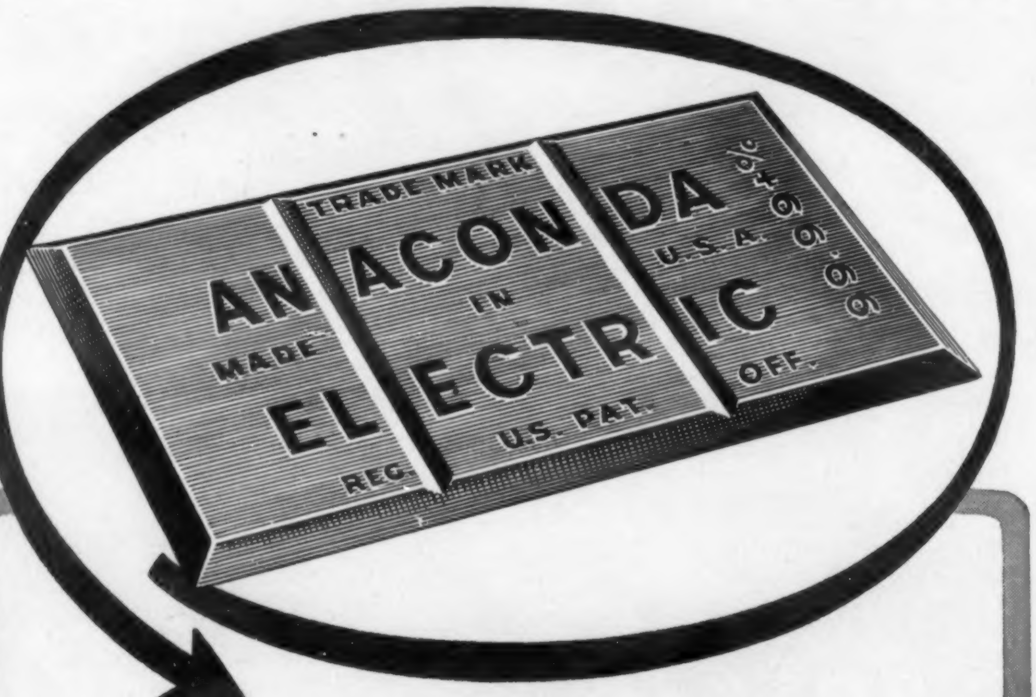
Stokeld believes that overheating is just one of the causes of blistering. Some specimens of blistered material and of the extruded bar before it was made into forgings show that in these particular cases there were discontinuities beneath the skin of the extruded bar. Above these discontinuities the blisters occurred.

Blisters are always found after heat treatment. The metal in the die is forced down to make a smooth surface, and it is only after it has risen that the blister occurs. The occluded gases in the area force up the surface and cause a blister.

On the other hand, one could have a piece of extruded bar without any work on it whatever and heat it carefully and have blisters. Each case has to be dealt with on its own merits.

Chadwick, referring to the relation between the extrusion defects and blisters in the forgings, stated that if the former are very close to the skin, they may give blisters even in the extrusion itself, before any work is done upon it. If a little deeper, a defect may give a blister in heating before it is forged, and if still deeper, it may not give a blister until it is forged. It may be so deep that it does not form a blister at all, but will show in machining.

The defect is never central, and generally contains a certain amount of organic matter that gives rise to the blister. If one exceeds the heat treatment temperature



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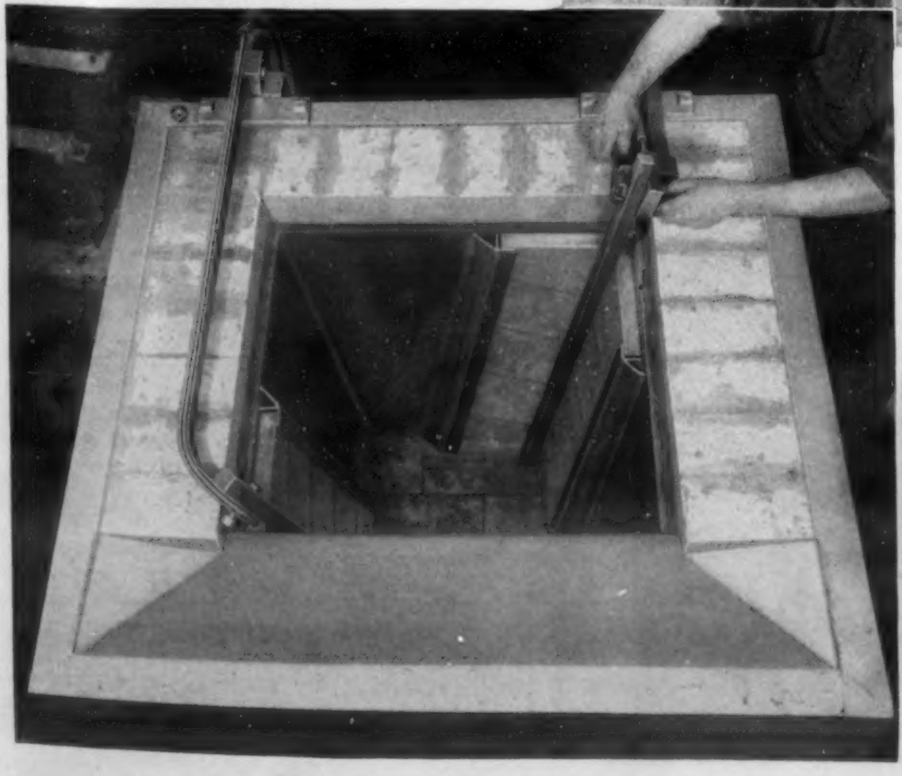

The single bolt connection with the water cooled bus bar permits changing electrodes in a few minutes time and without hoisting equipment. Keeping the connection cooled insures better current conductivity.

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by only 20° or 30° F., one will make the material a mass of blisters and the product will be ruined, and unless there is the proper equipment for heat treatment, this is very easily done. (2b)

Electroplating in Color

"ELECTROCOLOR AND PATTERNPLATE." J. E. STARECK (United Chromium, Inc.) *Proc. Am. Electroplaters' Soc.*, 1941, pp. 48-51. Descriptive.

The "Electrocolor" process produces colored finishes on brass, copper, or on copper-plated surfaces by electrolytic means.

The cleaned metal is made cathodic in an alkaline organic copper solution at a current density of 0.25-3.0 amp./ft.^{2} and a temperature of 70°-110° F. About 0.5 v. is required. A deposit of copper oxide (Cu_2O) is produced, which may have a variety of interference colors, resulting from interference effects when light passes through the thin oxide film.

The color obtained depends on the period of electrolysis, which controls the thickness of the film. As electrolysis is continued the color of the deposit goes through a certain sequence of color stages and then the cycle repeats. After about 9 cycles, the deposit takes on the red color of cuprous oxide.

The thinnest oxide coatings have the brightest hues, but because of their thinness must be protected by clear lacquers. The bath has good throwing power and an object of irregular shape receives a uniform color.

"Pattern-Plate" is a crystalline or fern-like ornamentation produced on metals through the intermediary of the electrocolor process. It is formed by the electrolytic reduction of the copper oxide deposit produced in the electrocolor process.

The reduction begins at isolated centers and spreads outward in a circular fashion until the discs merge together. The contraction resulting from the reduction of the less dense cuprous oxide to the more dense copper causes evenly and closely spaced radial or concentric lines to form which act as a diffraction grating and produce iridescent colors.

The adhesion of patternplate to the base metal is good, and sheet material can be put through forming operations without detriment. AB (2b)

Drawing (Sinking) Brass Tubing

"STRENGTH DISTRIBUTION IN SUNK BRASS TUBING." GEORGE SACHS, GEORGE ESPEY & G. B. KASIK (Case School of Applied Science) *Metals Technology*, Vol. 8, Oct. 1941, T. P. No. 1385, 6 pp. Experimental.

It has been reported frequently that the hardness and strength vary over the cross section of cold-worked, particularly cold-drawn, material. Brass rod and wire usually has been found to possess a maximum strength and hardness near the surface.

These differences are particularly large for wire given a small reduction on drawing through a die with a wide opening. However, with increasing reduction and hardness, a tendency to form a thin soft surface skin becomes apparent.

The increase of strength and hardness from the core to the skin is readily explained by the observation that, in addition to the stretching, the layers of a rod or wire are sheared more the closer they are to the surface. However, the presence of a soft surface layer can be attributed only to an annealing effect.

The source of such a softening might be the extremely high temperature that originates from the friction between gliding surfaces. In drawing, such a high surface temperature would be present for only a very short time at any particular section.

No similar observations have been made, as yet, on drawing *tubing*. Therefore, brass tubing drawn under various conditions was analyzed for the distribution of the strength in the cross section.

The simplest conditions in tube drawing are encountered in sinking; *i.e.* drawing without an internal tool. For sinking, only the outer surface is subjected to friction; and it should be expected that the discussed irregularities are restricted to a certain depth on the outside.

Therefore, several pieces of annealed cartridge-brass tubing, having varying outside diameter but a constant wall thickness of 1/32 in., were sunk to an outside diameter of ½ in., varying systematically the type and material of the die and the reduction. The reductions were actually measured and correspond to reductions of 6, 20 and 35% of the outside diameter.

The drawing was performed on an experimental hydraulic drawing bench with a speed of 7 ft. per min. The outside of the tubing was lubricated with castor oil. Each piece yielded 2 tensile-test specimens, which were tested for ultimate strength only.

Increasing reductions increase the average strength. The fiber having the maximum strength may be very close to the surface with small reductions but is moved farther away from the outside surface with large reductions.

Increasing die angle corresponding to a decreasing contact length between metal and die, affects both the average strength

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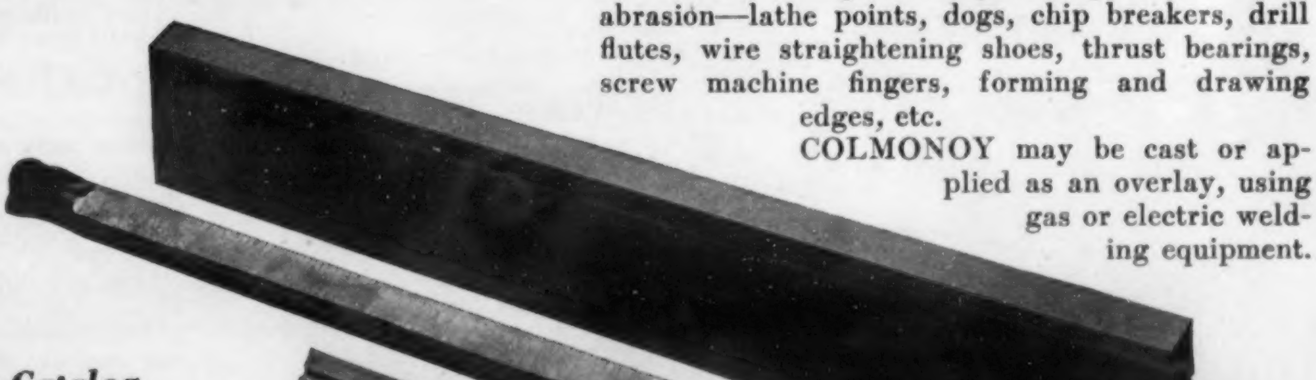

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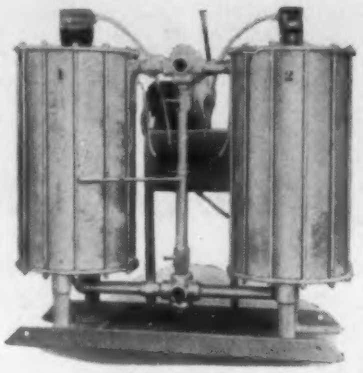

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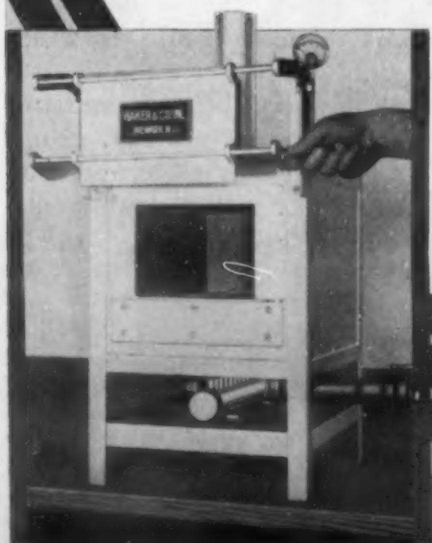

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and the strength of the inner fiber only slightly. The strength appears to be somewhat higher if the tubing is drawn through an acute die. However, the maximum is increased and shifted away from the outer surface with increasing die angle.

Tubing drawn with a low-friction tungsten carbide die has a strength distribution corresponding to that of tubing drawn by a smaller reduction with a chromium-plated die of approximately the same die angle.

It thus appears that there is a tendency to create a hard skin in tube drawing, this increasing in hardness with increasing die angle and increasing in depth with increasing reduction. The adverse tendency toward softening by annealing increases with increasing reduction and increasing die angle. This can be explained by the probable relations that while the surface heat developed increases approximately proportionally with the reduction, this surface heat is also dissipated faster as the contact area becomes larger. Also, the increase of hardness with increasing reduction and with increasing die angle will favor the softening. (2b)

Cyanide Plating—pH Control

"Measurement, Significance and Control of pH in Cyanide Plating Baths." Allen G. Gray (E. I. du Pont de Nemours & Co., Inc.) *Proc. Am. Electroplaters' Soc.*, 1941, pp. 36-47. Investigation.

The measurement of the pH of alkaline plating baths has heretofore been difficult because the quinhydrone and hydrogen electrode were not applicable. The colorimetric method and the glass electrode were subject to salt errors.

A new type of glass electrode material designated as type E, when used in alkaline solutions of sodium salts, gives values of pH that differ by only a few hundredths of a pH from the values obtained with the hydrogen electrode. With the glass electrode, caustic soda in a cyanide bath may be determined by titrating to a pH of 11.

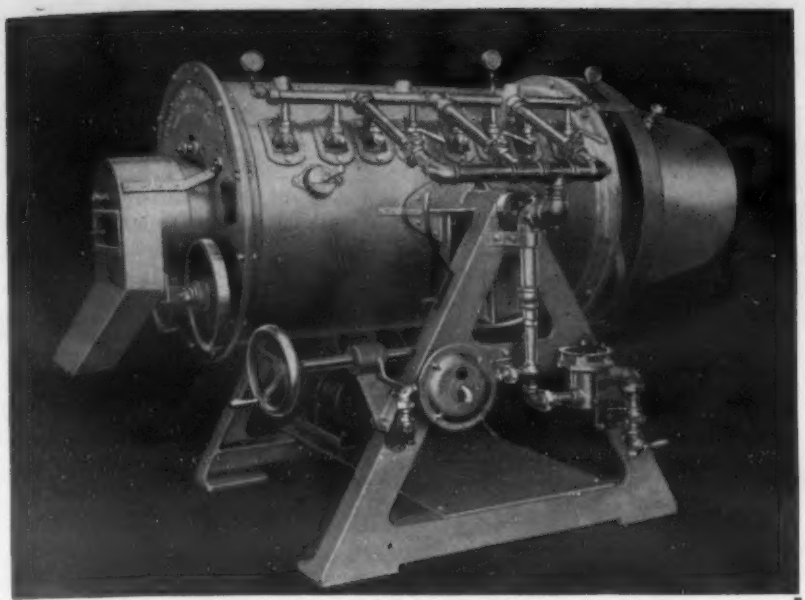
The character of the plating obtained at a given pH was studied over a range of current densities by means of the Hull cell. At a given pH, the deposit may be satisfactory over one range of current density and unsatisfactory over another range.

The cadmium cyanide plating bath is not sensitive to changes of pH at low current densities, but at current densities above 3 amp./dm.^{2} burnt, streaked, or spongy deposits may result if the pH rises above 12.0 for an ordinary bath or above 13.3 for a bright cadmium bath.

The ordinary copper cyanide (CuCN) bath operates best at a pH of 11.4-13.3. The cathode current efficiency approaches 90% as the pH increases. Above pH 13.3 the anode current efficiency falls off and the deposit becomes rough. In the copper cyanide-Rochelle bath, the optimum pH region is 12.4-13.3; at a lower pH, streaked deposits are obtained below 1 amp./dm.^{2} The Du Pont "high-speed" copper bath operates best at a pH of 13.3-13.5.

The optimum pH range for an ordinary zinc cyanide bath is about 13.5. The cathode current efficiency is high, regardless of pH, but the anode current efficiency decreases, as the pH is decreased.

The pH of a brass plating bath is important because it affects the composition and color of the deposit. For example, raising the pH increases the percentage of zinc in the deposit. The optimum pH for the ordinary brass bath is 10.6. For lowering the pH of a cyanide bath, sodium bicarbonate ($NaHCO_3$) is recommended. AB (2b)



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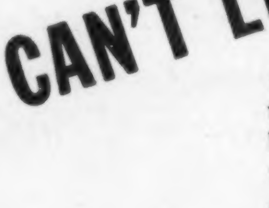

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3 Design and Applications

METALS, ALLOYS, METAL FORMS
ENGINEERING DESIGN, METAL SELECTION

Physical and Mechanical Properties (including Fatigue and Creep) • Corrosion and Wear • Engineering Design of Metal-incorporating Products • Selection of Metals and of Metal-Forms • Competition of Metals with Non-Metals • Specific Applications of Metals and Alloys

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Bearings and Surface Smoothness

A Composite

The performance of a bearing (as MIKELSON points out in one of the articles reviewed herewith) depends on several factors—surface roughness, surface hardness, inherent properties of the bearing material, lubrication, etc. In appraising bearings and their actual or possible performance under given conditions, none of these factors can be ignored, although only in very recent years has the influence of surface roughness received the attention it clearly deserves.

Increasing concern with this factor of surface smoothness—its importance, production and measurement—is reflected in the large amount of space given to it in current engineering literature. E. L. HEMINGWAY (see below) reminds us that the corollary effect of this is our present confusing array of conflicting ideas about surface finish, since each author is likely to have his own opinion as to what is or is not important.

Compromising Roughness and Smoothness

In an attempt to bring order out of this confusion, HEMINGWAY ("How Smooth Should a Surface Be?" *Iron Age*, Vol. 149, Jan. 8, 1942, pp. 40-45) points out certain defects common to bearing surfaces and offers a method of selection of surfaces.

Waviness is almost always present, even though surface measurements indicate a high degree of smoothness. Smoothness developed on a wavy surface will be much less satisfactory than the combination of smoothness plus perfection in surface "shape." A uniform oil-film thickness is obviously of great importance, but it is difficult to maintain if waviness is present.

The worst result of "smoothness plus waviness" is galling. Waviness will be forced through an oil film with more difficulty than will ridges, but the galling will be correspondingly more extensive. In those cases where lubrication completely fails, even perfect surfaces can be responsible for serious galling, but with reasonable lubrication, galling of surfaces that are both smooth and of perfect shape is practically impossible.

There are only two methods by which these ultra-smooth surfaces can be produced — lapping and "superfinishing." Where it can be applied, lapping produces the desired results, but it is often too slow and expensive. Superfinish is both efficient and inexpensive.

Where lubrication failure is likely, it is probably wise to break up the surface continuity to provide oil pockets and prevent galling from progressing to "freezing." But the idea of employing roughness to restrict this type of galling has its limitations; there will surely be rapid wear and increase in clearance dimension, for example. And in the customary operating condition —*i.e.*, with reasonable lubrication—rough surfaces are quite likely to gall.

The suggested method of "compromising" this situation is to reduce the roughness and waviness so that all of the extreme outside dimension is contained in one geometrically true plane, whether it be cylindrical or flat. Beneath this plane should be varying percentages of area devoted to grinding pits, etc., to act as oil pockets. The variation in that percentage should depend on lubrication conditions and on the galling capacity of the metals employed.

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Lubrication of Smooth and of Rough Bearings

A comparison of the operating performances of smooth and of rough bearings under various lubrication conditions is given by W. Mikelson of Gen. Electric Co. ("Relation of Bearing Surface Condition to Bearing Performance," *Gen. Elec. Rev.*, Vol. 44, Dec., 1941, pp. 669-672). The article describes a new method of evaluating bearing performance by recording the vibration it produces when used as a sleeve bearing in conjunction with the shaft of a small motor.

In studying bearing vibration, measurements are taken of total vibration by making a "frequency analysis," which gives the intensity of each individual frequency component present in the vibration. Equipment was used with which a continuous record could be made automatically of the frequency spectrum within the range specified—here, 50 to 2000 cycles/sec.

For a rough bearing, both high-frequency and low-frequency components of the vibration were increased, but the magnitude of the increase was considerably greater at higher frequencies. The vibration without lubrication on a smooth bearing was generally much greater (about 20 to 1) than when lubricated, even under highly adverse bearing conditions.

The damage done to the good bearing by running it at 5-min. intervals for a total of ½ hr. without lubrication seemed to produce a worse bearing condition than deliberately scratching the shaft and bearing with a sharp tool. Relubricating the bearing after running dry improves the performance over the dry condition but never to its original level.

One interesting exception to this arises when the original bearing condition was unusually rough. Running a rough bearing dry sometimes smooths out the rough spots and results in slightly improved performance when lubrication is restored.

The actual influence of surface roughness on bearing performance varies with the type of lubrication, according to J. T. Burwell, J. Kaye, D. W. van Nymegen & D. A. Morgan ("Effects of Surface Finish," *J. Applied Mechanics*, Vol. 8, June, 1941, pp. A49-A58). While the performance of journal bearings can be accurately described by the hydrodynamical theory when operating under light loads and high speeds, the theory ceases to apply if the bearing operates at higher loads and lower speeds.

It was found that surface finishes produced in different ways and having roughness ranging from 130 to 1 microinch (measured by their root-mean-square deviations from a median plane) have little or no effect on the performance of a partial journal bearing while it is operating under hydrodynamic lubrication. However, the lower limit of the region of hydrodynamic lubrication (as indicated by the minimum of the friction coefficient) is markedly dependent on the surface finish of the journal, for it decreases as the surface becomes smoother.

This result implies an increase in load capacity of the bearing with increasing smoothness and it thus becomes evident how important it is to reduce the surface roughness which should be at least less than 15 microinches. The experiments also show that the running-in period is of short duration, about ½ to 1 hr. A straight-line relation exists between the total wear at the end of 2 hrs. and the degree of surface finish, if constant pressure is employed.

X (3)

Rote

3a. Ferrous

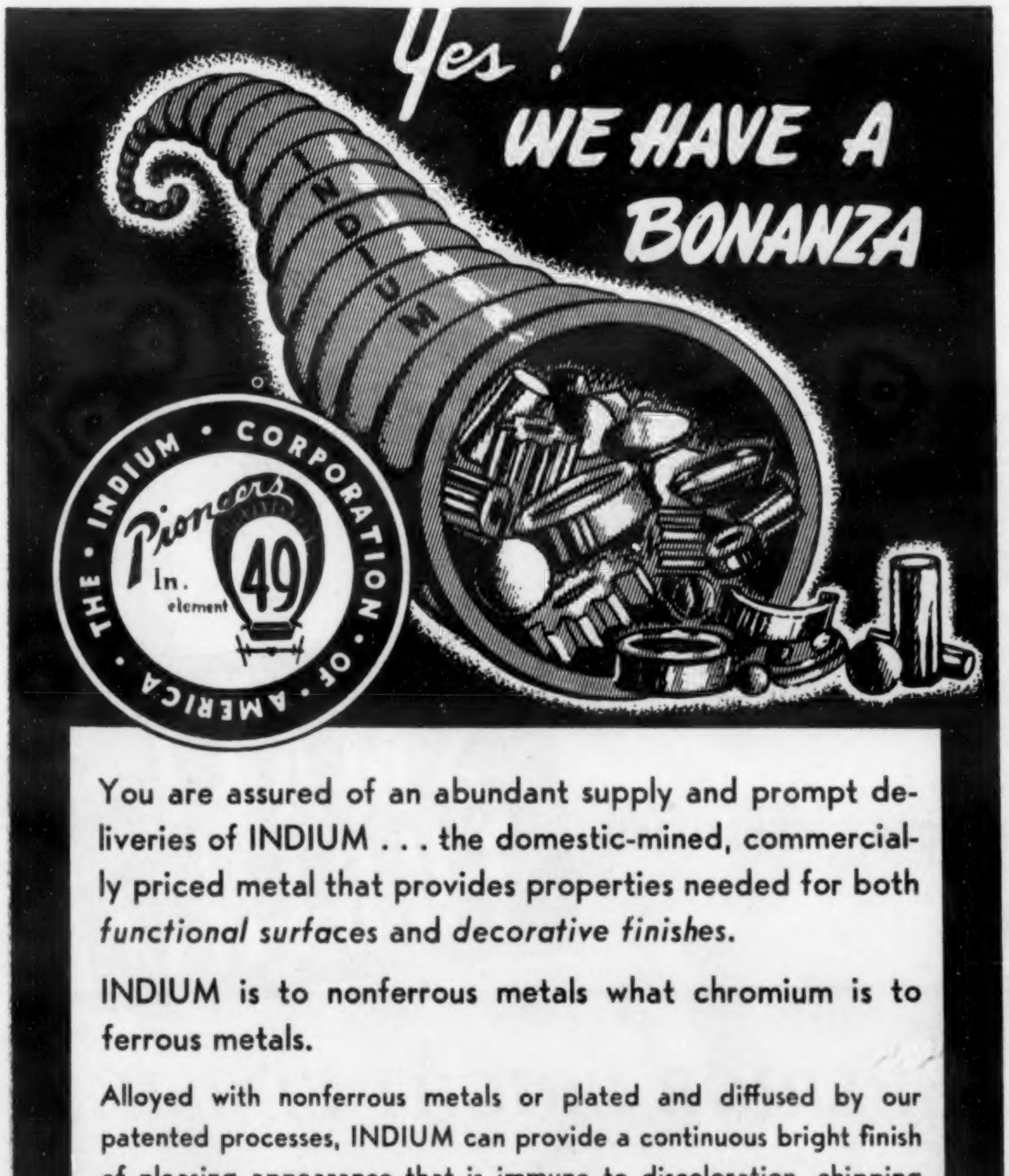
Alloy Cast Irons

"Alloy Additions to Gray Cast Iron." G. A. Timmons & V. A. Crosby (Climax Molybdenum Co.) *Foundry*, Vol. 69, Oct. 1941, pp. 64-66, 145-147; Nov. 1941, pp. 62-63, 144-147. Investigation.

One way of making high-strength cast iron is to make alloy additions to the ladle. Many castings are stress-relieved or annealed before being put in service, and it is advantageous to know how various alloys may influence the resistance of the iron to hardness breakdown.

In order to furnish a basis for recommendations and specifications, a base iron of about 3.25% C and 2 Si was made and 13 alloyed irons were produced by making ladle additions to the base iron. The melts were superheated to 2800° F., and late addition of 0.25% Si was made to each ladle from pulverized 75-80% ferrosilicon. Test bars were cast at 2600° F. and cooled to room temperature, and tests were made for transverse tensile strength, Brinell hardness, structure, etc. The annealing temperature required to produce a hardness of 207-217 was also ascertained.

The major effect of alloy elements is to lower the temperature of austenite decomposition upon cooling, thereby producing pearlite with finer lamellae and greater hardness. All the elements used in these tests are known to stabilize the austenite or reduce the rate of transformation, forcing the austenite to transform at lower



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subcritical temperatures upon cooling at a constant rate. These individual effects depend on the potency of the element itself, the quantity present and the behavior of combinations of alloy elements.

Molybdenum stabilizes the austenite upon cooling from casting temperature. Thus, the addition of about 0.50% Mo increases the strength and Brinell hardness in the as-cast condition. This increase in strength varies from 4500 lbs./in.^{2} for a chromium-iron to 10,000 lbs./in.^{2} in the case of a chromium-nickel iron.

The stability of the as-cast structure is associated with diffusion of carbides at the annealing temperature, and for most irons this governs the hardness after annealing or after drawing at temperatures below 1450° F. When the irons are heated above the critical temperature and the matrices become austenitic before the irons are again cooled to room temperature, the final microstructures will depend upon the rates of austenite decomposition at the various temperature levels passed through during cooling.

Hardness breakdown in this range indicates effects of elements upon this rate of diffusion at the different temperatures used. Irons with chromium offered greatest resistance to hardness breakdown in the range 1100°-1400° F.

After annealing at 1400° F., chromium-molybdenum iron possessed the highest hardness and tensile strength. Except for chromium irons and chromium-nickel-molybdenum irons, the alloy irons showed lower hardnesses after annealing at 1600° F. than at 1500° F.

To provide a basis for determining why alloy irons with the same total carbon and graphite as plain iron will possess superior tensile strength when tempered to the same hardness, metallographic specimens were examined. Molybdenum-vanadium iron was drawn to 212 Brinell, tensile strength of 42,600 lbs./in.^{2}

The comparison of microstructures showed that the plain (base) iron, as-cast, possessed a Brinell hardness of 217 so it was not drawn (hence it contained a pearlitic matrix). VSP (3a)

have card

Creep and Recovery

"The Creep Recovery of a 0.17 Per Cent Carbon Steel." A. E. Johnson. *Proc. Inst. Mech. Engrs.*, Vol. 145, Oct. 1941, pp. 210-220; abstracted in *Bull. Iron & Steel Inst.*, Nov. 1941, p. 34A. Investigation.

The author describes an investigation, for the case of a 0.17% C steel, of the relation between the recovery after a creep test and the conditions of stress, temperature, period of test and strain during the test.

Creep and recovery tests were made with apparatus capable of measuring creep rates of the order of 10^{-8} in. per in. per hr. at temperatures of 800°, 850° and 900° F. for periods of 0.2, 2, 20 and 145 hrs. The following conclusions were reached: At a given temperature, and for any particular period of creep test, the recovery curves at all stresses are geometrically similar. At each temperature, and for any fixed period of creep, recovery varies directly as the stress applied.

Recovery increases with temperature over the range 660°-1020° F., from about 3% of the initial elastic strain at 660° F. to 52% at 1020° F. Over the small range of temperature, 800°-900° F., the recovery seems to increase approximately linearly with temperature.

As the period of creep test preceding recovery is increased, the amount of recovery at a given stress also increases up to a maximum value at the commencement of the period of minimum creep rate, and does not further increase while the minimum creep rate is maintained. The time necessary to complete the recovery of the material increases with the duration of the creep test up to the period of minimum rate, and does not further increase while the minimum rate is maintained.

No simple relation between creep strain and recovery strain could be found. The results appear to confirm that recovery is bound up with the partial or complete release of stress concentrations built up during the creep test, and that stress concentrations become more intense as the creep test proceeds, thereby increasing the amount of recovery. (3a)

3b. Non-Ferrous

Aluminum Alloy Armor Plate

"Effect of Projectiles on Strong Light Alloy Plates." *Light Metals*, Vol. 4, Dec. 1941, pp. 234-236. Investigation.

Light alloy plates of "Avional D" (3.8% Cu, 0.55 Mg, 0.5 Mn), "Anticorodal B" and "Anticorodal C" (aluminum-silicon-magnesium-manganese alloys) were used in a series of tests in which bullets were fired under various conditions at the plates held around the periphery.

The mechanical properties of these alloys are as follows: Avional D—54,000-60,000 lbs./in.^{2} tensile strength, 14-20% elongation, 34,000-42,000 lbs./in.^{2} 0.2% proof

Leadscrew nuts in Landmaco Threading Machine, product of Landis Machine Company, Waynesboro, Pa.

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Advertisement FEBRUARY, 1942

COPPER ALLOY BULLETIN

REPORTING NEWS AND TECHNICAL DEVELOPMENTS OF COPPER AND COPPER-BASE ALLOYS

Prepared Each Month by the Bridgeport Brass Co. "Bridgeport" BRASS CO. *Headquarters for BRASS, BRONZE and COPPER*

New Uses Seen for Duronze II as Substitute for Copper-Tin Alloys

Properties of Bridgeport's Copper-Silicon Alloy Suggest Applications in Spring Parts Instead of Phosphor Bronze

Under present conditions, industry is faced with the problem of finding substitutes for tin in its various uses as a pure metal and in alloys. How soon the lack of tin will become a serious problem is difficult to determine, but it seems probable that some curtailment will be necessary.

In the wrought copper alloys, the greatest use of tin is in the phosphor bronzes, which contain from 3.5 to 10% of tin. While substitutions for tin in some fields may be difficult to accomplish, in the case of phosphor bronze much work has been done to provide suitable substitutes.

Possible Substitutes

As in many other cases, substitution necessitates sacrifice of certain characteristics, and may result in improvements in other characteristics. There are several alloys which have been used in place of phosphor bronze in industry, and the selection of a substitute depends largely on the nature of the application. In most applications of phosphor bronze, spring characteristics are necessary. Nickel silver has been used as a substitute, particularly in flat spring clips. Nickel, however, is so much more important in other uses that nickel silver also has become difficult to obtain. High brass may also be used for such purposes, but has certain disadvantages in the possibility of stress corrosion failures and in somewhat lower fatigue life.

Considerable study has been given to the use of silicon bronze alloys, such as Duronze II, in place of phosphor bronze. Fig. 1 shows the relative rolling characteristics of Grade A phosphor bronze and of Duronze II (3% silicon-copper alloy). It is notable that the silicon copper is appreciably harder and stronger, but that the elongation of the phosphor bronze is greater, particularly in the annealed and less severely cold worked condition.

Annealing Characteristics

The annealing characteristic curves (Fig. 2) also indicate similar differences in physical properties. It is probable that some of these differences are due to the retarded rate of recrystallization and grain growth in the silicon-copper alloy. It seems clear, however, that Duronze II is a stronger and somewhat less ductile alloy than Grade A phosphor bronze. In so far as flat spring clips and spring materials in general are concerned, the greater strength of the silicon bronze is advantageous. If comparisons are made with the properties of 8% phosphor bronze (shown in the Alloys of Copper column in the December, 1941, COPPER ALLOY BULLETIN), it may be seen that they are very similar to those of the 3% silicon alloy. There is therefore no reason why silicon bronze spring clips cannot be produced of equal hardness or even greater hardness than phosphor bronze.

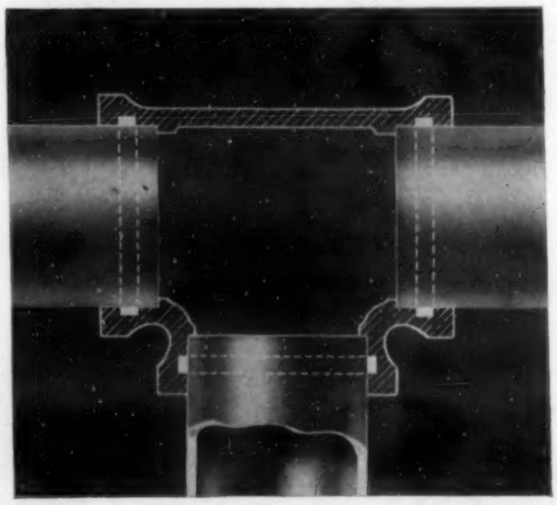
(Continued on page 2, column 2)

Installation, Service Advantages Offered by Bridgeport Tubing

Economical installation and durable service are among the advantages offered by Bridgeport "Navy-Type" copper tubing which is widely used for modern marine construction and maintenance.

The range of wall thicknesses of this tubing meets all U. S. Navy test pressure specifications from 100 to 4,500 pounds. Connections are made with threadless Bronze fittings joined with pre-inserted rings of Sil-Fos Brazing alloy, thus providing a stronger, tighter connection that dependably withstands vibration failure.

Bridgeport copper tubing is produced in types, sizes and gauges suitable for conveying water, oil and steam; for sanitary systems and refrigerants; and for other special uses outlined in U. S. Navy and Maritime Commission specifications. Full information on this tubing, as well as condenser and heat exchanger tubes, will be sent on request.



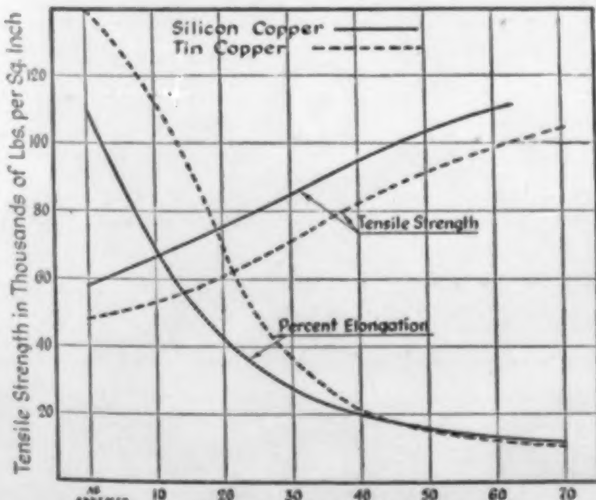


Fig. 1. Comparative rolling characteristics of 5% tin-copper alloy and Duronze II (3% silicon-copper alloy).

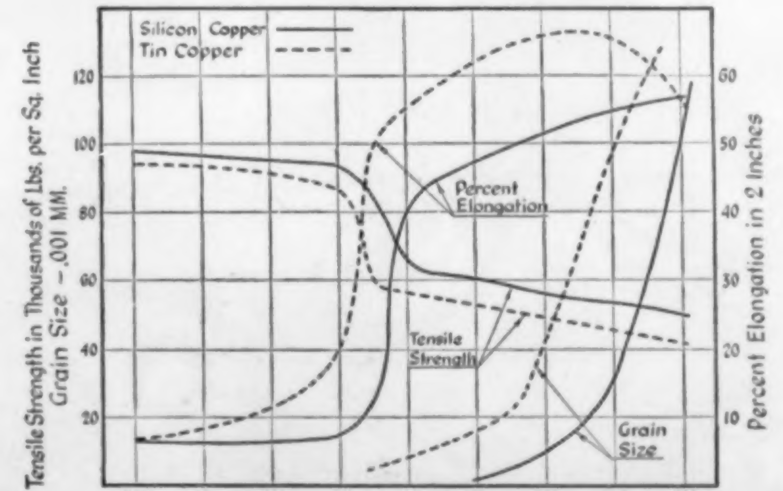


Fig. 2. Comparative annealing characteristics of 5% tin-copper alloy and Duronze II (3% silicon-copper alloy).

COPPER ALLOY BULLETIN

ALLOYS OF COPPER

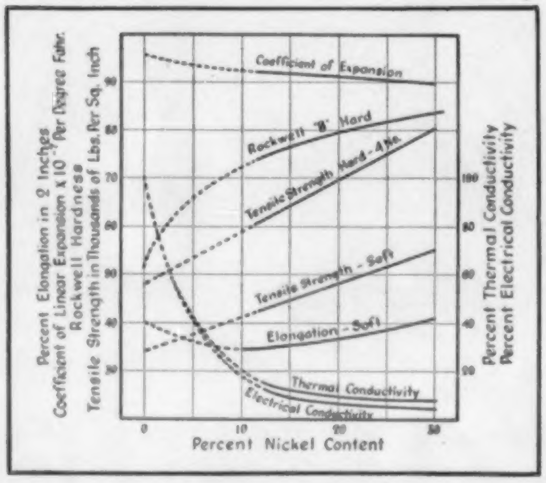
This is the thirty-first of a series of articles on the properties and uses of the copper alloys.

ALLOYS OF COPPER WITH NICKEL

Copper and nickel alloy to form solid solutions in all concentrations. Hence usable alloys can be made with nickel contents from less than 1% to more than 99%. Only alloys containing less than 50% nickel are considered copper alloys. As the high mutual solubility does not make for great changes in properties as the nickel content is increased, relatively few copper-nickel alloys have any considerable commercial use.

The curves below show approximate values for physical properties of the commercial alloys containing 15-20% and 30% nickel. Data for alloys containing less than 15% nickel consist of interpolations of the data for the 15% nickel alloy and pure copper.

The first additions of nickel to copper do not have any very marked effects on its physical properties. Tensile strength increases slowly, and the real advantages of copper nickel are obtained only with higher nickel contents. Addition of nickel tends to increase corrosion resistance under some conditions, and improves resistance to oxidation at elevated temperatures. The high electrical resistance makes the alloys suitable for resistance wire. All of the properties are very nearly equaled, and in some cases surpassed, by alloys in which zinc replaces some of the copper. Since such alloys are cheaper than cupro nickel, they are quite generally used in place of it. Chief use of cupro nickel is that of the 30% alloy for condenser tubes in marine service. This alloy is standard in the United States Navy for this purpose.



Physical properties of cupro nickel. Dotted lines indicate estimated values.

Bronze Welding Helps Maintain Production

The difficulty of getting replacement parts has given added importance today to the use of bronze welding for the repair of broken equipment. Manufacturers in many lines have found that Bridgeport Bronze Welding Rods make strong, lasting welds on jobs of any size, large or small.

Such satisfactory results are obtainable with Bridgeport rods because they are pure, reliable and uniform. They may be used on all cast iron, steel, and bronze work. The Bridgeport Brass Company has published a "Manual on Bronze Welding Alloys" which will be sent to you on request.

Memos on Brass—No. 25

The term "brass" includes a great variety of copper-zinc alloys and a surprising range of physical properties which can be greatly modified by:

(1) Changing the composition.
  (a) Modifying the proportions of copper and zinc.
  (b) Additions of small amounts of lead, tin, aluminum, iron, arsenic, etc.
(2) Changing the temper—ductility, hardness, strength, etc.
  (a) Heat treatment to produce various gradations of softness and ductility.
  (b) Cold working (reduction by rolling or drawing without subsequent annealing) to produce various gradations of hardness and stiffness.

Uses of Duronze II

(Continued from page 1, column 2)

There are, of course, other factors which are important in the proper functioning of flat spring clips. The physical properties indicate that Duronze II has a forming capacity at least equal to that of phosphor bronze. These bending and forming characteristics have been checked by actual bending tests which show that the silicon bronze will take bends of about the same severity as phosphor bronze. Fatigue characteristics are determined by endurance tests, and the data obtained indicate that there is not an appreciable difference in the endurance limits of the two alloys.

The properties of these alloys, with reference to their use in springs, will be considered further in a future issue of the COPPER ALLOY BULLETIN.

NEW DEVELOPMENTS

A soldering-iron stand is said to speed operations on small parts. The iron is held in an adjustable clamp while a 30-inch pipe acts as a chimney to carry off fumes. A hood at bottom of the pipe is provided with a magnifying glass or with ¼-inch plate glass and has two lamps underneath it to illuminate the work. **(No. 290)**

A new vise with fast opening and closing jaws is designed particularly for high production milling, drilling and tapping operations on small parts. Two levers are used, one for forcing the work against the jaws and the other for locking them. Three sizes, 4-, 5-, and 7-inch, are available. Maximum working openings with both jaws are 1 13/16, 2 5/16 and 3 13/16 inches. **(No. 291)**

A drill container consists of a brass cylinder with a solid bottom and a knurled rotating top with individual compartments for drills from No. 1 to No. 60. A small knob in the top is positioned in a slot to bring an internal finger under the drill desired. The assembly is 5 inches high and 2 3/16 inches in diameter. **(No. 292)**

A new low-temperature paste has been designed that is said to clean as it fluxes and to be quick acting in the soldering of all nonferrous metals. **(No. 293)**

Pipes or tubes can be bent or straightened without the use of heat or auxiliary equipment, it is reported, with a portable hydraulic pipe bender. Curvatures are limited only by the radii or bending shoes. One handle and one release valve control the ram. It bends 7 sizes of pipe and when equipped with attachments is claimed to perform scores of maintenance and production jobs. **(No. 294)**

A portable metal saw with a continuous saw blade has been developed. Three speeds allow the cutting of almost any shop material and no coolant is required, the maker asserts. Made in two sizes. **(No. 295)**

Tinning and cleaning can be done in the same operation, it is claimed, with a new tinning compound. No acids or fluxes are necessary, and paint does not have to be removed, it is reported. **(No. 296)**

A metal cutting machine, which occupies four square feet, has been designed for high speed cutting on rounds, squares or tubes of brass, bronze, or copper. The cutting wheel or saw blade is driven by a two-speed electric motor which develops 2½ and 5 horsepower. Drive is through five V-belts. **(No. 297)**

A motor-driven lathe has been designed with a six-position turret having six 1½-inch diameter tapped holes in each turret face for mounting various sizes of tool holders. It also has a plain saddle on which a variety of tool posts or other fixtures can be mounted. Either worm drive or direct drive is available. **(No. 298)**

This column lists items manufactured or developed by many different sources. Further information on any of them may be obtained by writing Bridgeport Brass Company, which will gladly refer readers to the manufacturer or other source.

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COPPER WATER TUBE — For plumbing, heating, underground piping.

DURONZE ALLOYS — High-strength silicon bronzes for corrosion-resistant connectors, marine hardware; *hot rolled sheets* for tanks, boilers, heaters, flues, ducts, flashings.

BRASS, BRONZE, DURONZE WIRE— For cap and machine screws, wood screws, rivets, bolts, nuts.

FABRICATING SERVICE DEPT.—Engineering staff, special equipment for making parts or complete items.

BRASS AND COPPER PIPE—"Plumrite"* for plumbing, underground and industrial services.

BRIDGEPORT BRASS

stress, 100-115 Brinell; Anticorodal B—45,-000-52,000 lbs./in.^{2} tensile strength, 10-14% elongation, 38,000-42,500 lbs./in.^{2} 0.2% proof stress, 90-100 Brinell; Anticorodal C—51,000-60,000 lbs./in.^{2} tensile strength, 2-6% elongation, 47,000-54,000 lbs./in.^{2} 0.2% proof stress, 110-120 Brinell.

Examination of the areas of impact showed that fully heat-treated Avional D behaved perfectly plastically, while hardened steel would have tended to crack and splinter. Hence, the use of such materials as Avional D offers less risk of fragmentation. Light alloys might be satisfactory against small arms projectiles because of their "sand bag" effect.

However, in the tests cited, it appeared that the favorable protection offered by the aluminum alloys was due in part to the use of bullets that were themselves fairly readily deformed. A harder bullet undoubtedly would have passed through with much less difficulty. On the other hand, it was shown that all the aluminum alloys behaved plastically in the tests.

The advantages of aluminum alloy plate in working up into shape as compared to carburized or even ordinary armor plate steel are, of course, obvious. The protective value of strong aluminum alloys appears to be roughly the same as that of steel armoring of the same weight.

The possible advantages of a combination of steel and aluminum for armoring are very attractive: steel for hardness and ability to blunt the point of the bullet, and aluminum for energy absorption. AUS (3b)

Designing with Magnesium Alloy

"Economic Design for Magnesium Alloy Construction." (In German) Max Schonberg. *Automobiltech. Z.*, Vol. 44, June 25, 1941, pp. 295-305. Condensed translation in *Engineer's Digest*, Vol. 2, Sept. 1941, pp. 328-331. Practical.

Strength consideration has been traditionally the primary factor affecting engineering design. With the light alloys, however, emphasis is shifted to the elastic modulus of the material.

Although the standardized strength figures of the light alloys form the basis of design calculations, these have to be reduced in practice since they refer only to static conditions of loading. Consideration must also be given to actual working temperatures, wear and abrasion resistance, friction and surface characteristics, corrosion resistance and local overstressing.

The inferior strength of magnesium alloy as compared with iron and steel, can be compensated only by an enlargement of the cross-sectional area of the stressed member. This principle holds for all manner of stresses, *e.g.* pure tension or compression, bending or shearing.

Owing to the much larger strength/weight ratio of electron and other light alloys, the practical saving in weight of structure is still considerable. When buckling occurs, an improvement can be obtained, apart from increasing the cross-sectional area, by providing support.

Holes for rivets or bolts weaken the material, and in this case the remedy is to use larger cross-sections. The effect of these holes is similar to that of sharp bends causing local over-stressing, to which magnesium alloy is particularly sensitive.

Magnesium alloy castings find a wide application in the German motor car industry. It is possible to prepare castings of dimensions and wall thicknesses that would not be feasible in heavy metals be-

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Tuesday, December 9th, 1941

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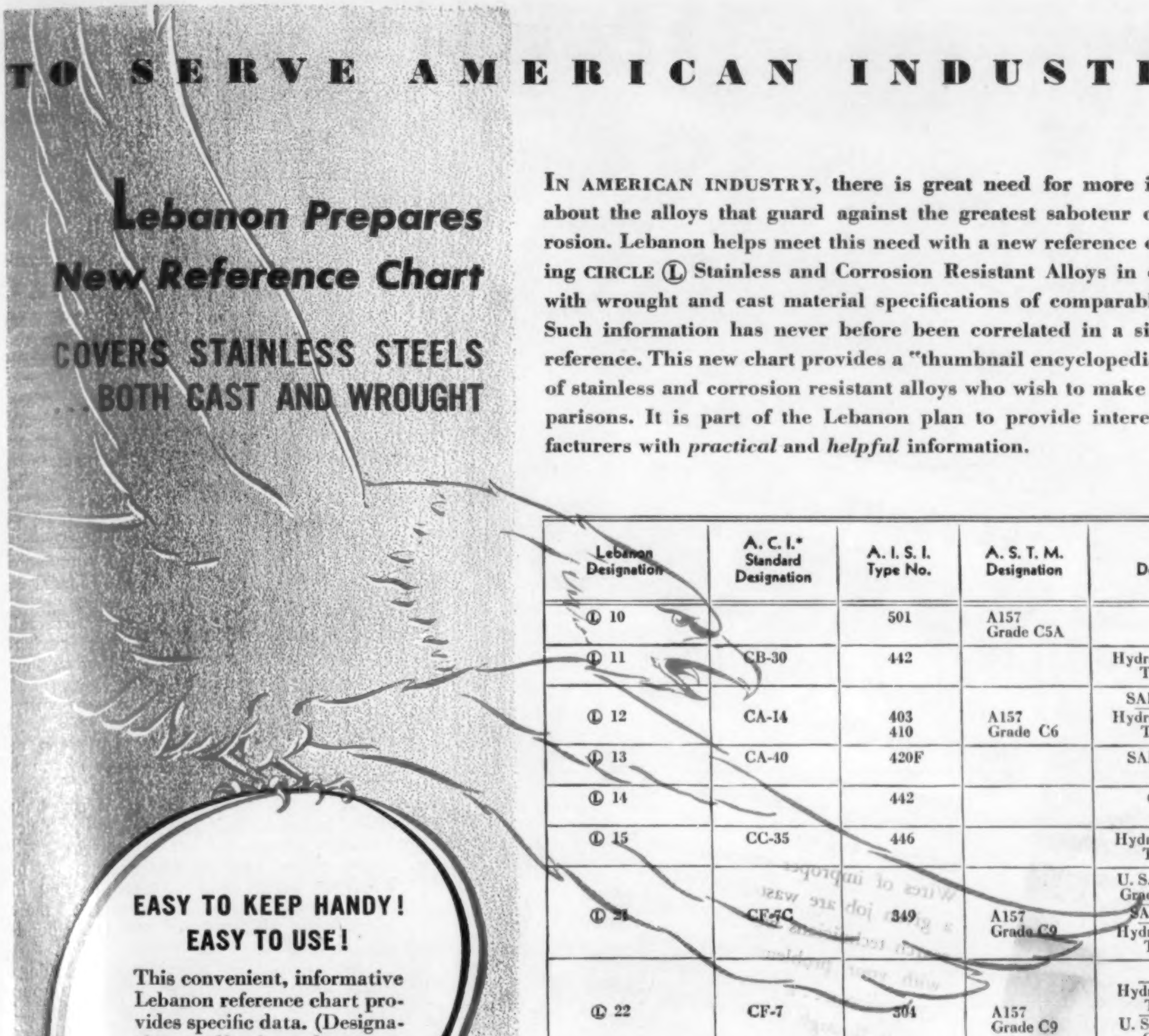

Lebanon Prepares New Reference Chart

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Ⓛ 23M	CF-20SE	303	A157 Grade C9	SAE No. 30615 Type 2
Ⓛ 23XM	CF-20M		A157 Grade C9	KA2Mo.
Ⓛ 24	CM-25	325	A157 Grade C10	
Ⓛ 25	CG-20			
Ⓛ 30	CH-20	309		
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Ⓛ 30XM	CH-20M			
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cause of weight considerations. Sand, permanent mold and die castings are equally suitable.

Fabricating the article by casting is especially suitable for magnesium alloy. Moreover, the small value of elastic modulus allows a large deformation of the material before fracture. As an example, a magnesium alloy wheel used on a mobile gun is cited, which has stood up excellently to the stresses and shocks throughout several years' service.

The work has to be designed with small stresses along the edges. The use of collars is recommended wherever high tensile stresses may be present at the periphery of the section. This applies also to the circumference of holes and to H sections.

On the other hand, accumulation of material should be avoided if possible, otherwise internal stresses may be produced owing to differential cooling. At points where the load is applied this cannot be prevented, as these parts have to be massively designed. From these points the stress should be uniformly transmitted to thinner sections by providing an adequate number of ribs or webs. All transitions from heavier to lighter sections should be gradual.

As a protection against corrosion, all parts should be designed without pockets or recesses so that the water can flow away freely.

Bearing and supporting surfaces carrying heavy stresses should be reinforced with heavy metals. Overdimensioning of these parts is dangerous, because of warping, which might occur during cooling.

The usual method of fastening light alloys is by bolting. It is sound practice to use a greater number of bolts of small diam. rather than a smaller number of bolts of larger diam. Thread cutting in magnesium alloy is allowable only if there is sufficient thickness of metal surrounding the hole.

Magnesium alloy pressings and forgings for machine parts form an important group in industrial application. Their mechanical properties are superior; they offer a better surface and require less finishing; stress distribution also becomes more uniform. The forging of magnesium alloys makes it possible to construct machine parts in one piece, which formerly had to be fabricated in two or more parts, and in this way further saving of material is achieved.

Elaborate profiles can most easily be obtained by pressing. Another important feature of pressed parts is that they can be bent and formed. This is best performed at about 480°-570° F. (3b)

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Bend Tests for Weld Cracking

"WELDABILITY CRACKS AND BRITTLENESS UNDER EXTERNAL LOAD. PART II—TESTS FOR CRACKING UNDER EXTERNAL LOAD: BEND TESTS. A REVIEW OF THE LITERATURE TO JULY 1, 1939." W. SPRARAGEN & G. E. CLAUSSEN. *Welding J., N. Y.*, Vol. 20, Sept. 1941, pp. 369s-401s. Correlated abstract of 121 references.

The four chief tests for demonstarting the ability of a weld to resist external load are the bend, notch impact, hardness and tensile tests. There are 5 types of bend tests: (1) free bend, (2) plunger bend, (3) bead bend, (4) fillet, and (5) weld quench (German) bend tests.

Tests (1) and (2) are used for butt welds, (3) for single bead weld, and (5) for base metal heat treated to exhibit the same microstructure as the heat-affected zone of a weld. Beyond an empirical relation between bend elongation and reduction of area in a tensile specimen, bend values cannot be expressed in terms of more fundamental properties of a material.

Bend angles are higher in the free bend test than in the plunger (guided) bend test. The latter is widely used in Europe and appears in A. W. S. qualification procedure (for the latter the angle at which a crack ⅛ in. long appears is noted). Rigid control of testing condition is imperative and results exhibit considerable scatter.

A difference in bend angle between hard and soft steels does not necessarily connote a difference in a capacity for deformation because the hard steels "peak" or leave the plunger, resulting in a smaller bend angle. Depending upon the dimensions, the elongations of weld metals that passed a British specification for 180° bend varied from 12½% to 57%. Confusion enters any comparison of bend elongations through failure to state the gage length.

The bead bend test is widely used in Germany for specimens ¾ to 2 in. thick, which are bent longitudinally (along the weld). The usual measurement is the bend angle at the first crack that starts at the fusion line. The type of fracture is sometimes noted; whether (a) sudden, with the crack propagating at once through the thickness, or (b) a ductile, slow break.

Although wide variations were secured with different steels, it was impossible to correlate the differences with composition. One investigator found that the lowest bend angles coincided with the highest hardness in the heat-affected zone. The high bead-bend angles to complete fracture exhibited by steels treated for fine McQuaid-Ehn grain size and for inclusion distribution were associated with fibrous fracture. Finely divided bands of inclusions forced the crack, which started in the weld metal or the heat-affected zone at the same angles as in untreated steel, to change its course.

Basic Bessemer steel was inferior to open hearth steel of approximately the same composition. Killed steels were no better than rimmed heats.

It appears that normalizing may affect the bend angle at the first crack to a small extent, but that its most striking benefit, which it not always confers, is in raising the angle through which the specimen holds together after the first crack. Very high bend angles are obtained for specimens given a stress relief or normalizing treatment after welding or where preheating is employed. High hardness in the heat-affected zone is usually associated with low bend angles, but some tests with mild and low alloy steels show no relationship between hardness and bend angle.
WB (4)

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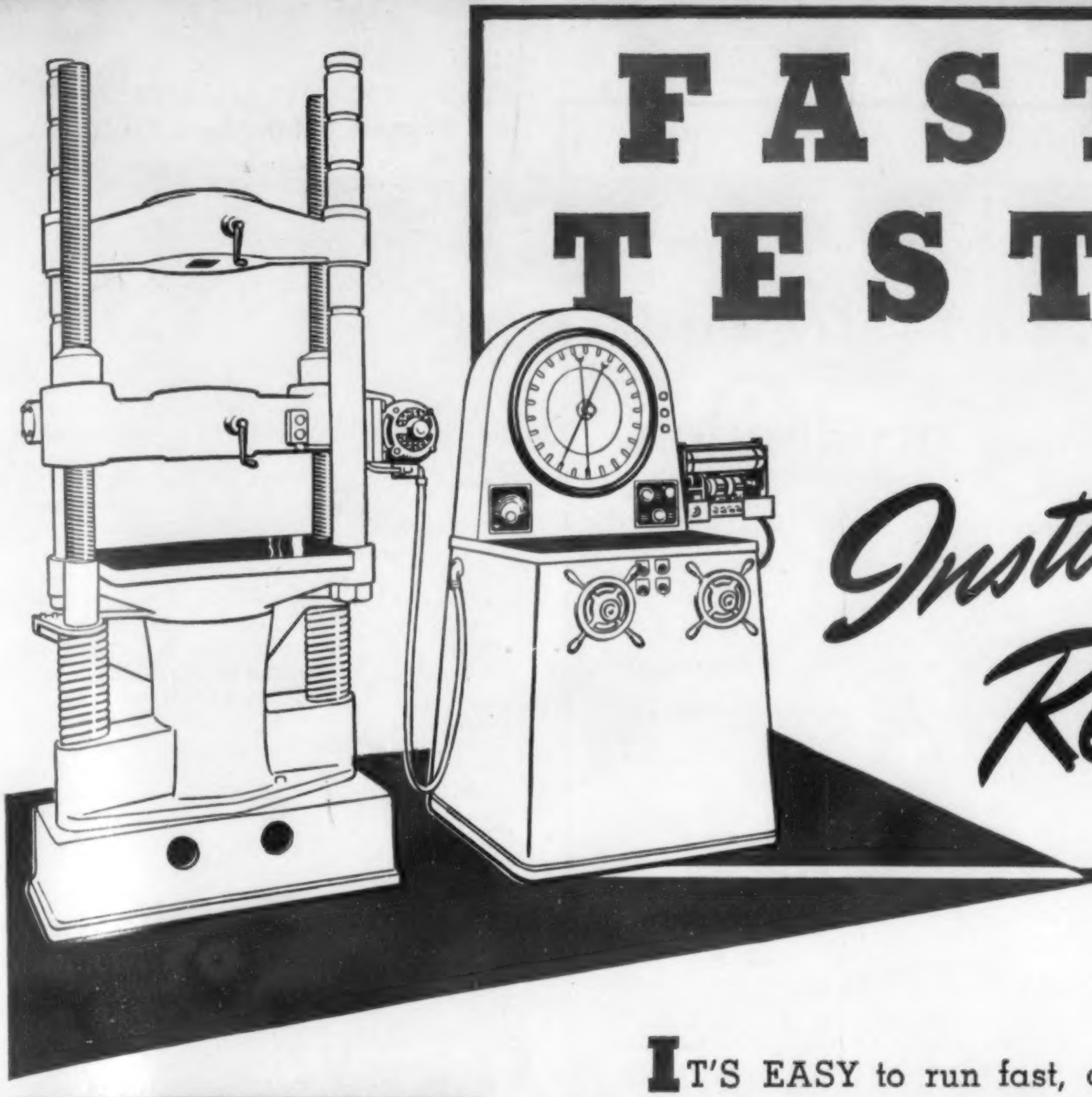

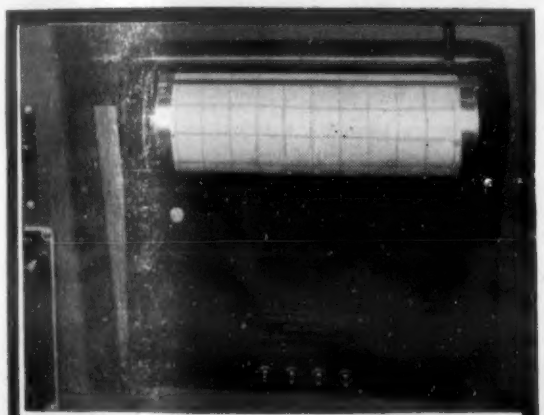

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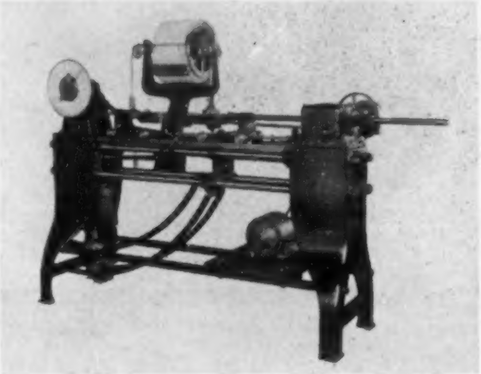

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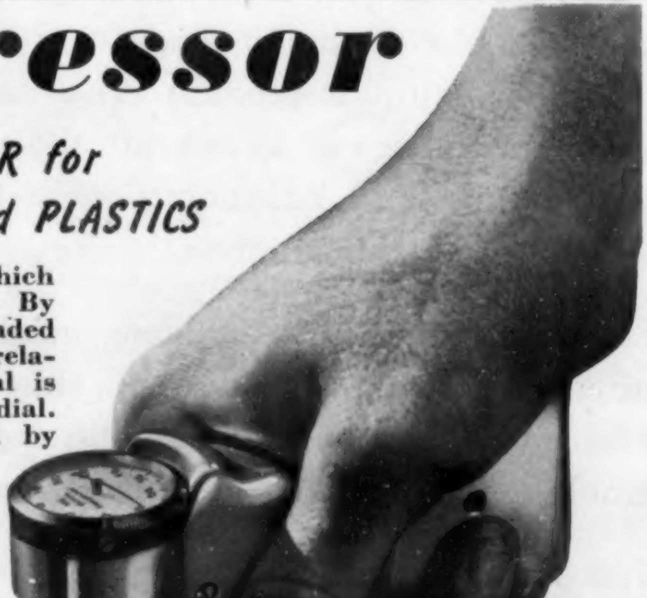
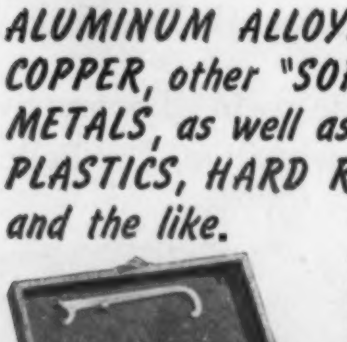




Dynamic Hot-Hardness Testing

"Dynamic Hardness Testing of Metals and Alloys at Elevated Temperatures." Erich Fetz (C. O. Jelliff Mfg. Corp.) *Am. Soc. Metals,* Preprint No. 38, Oct. 1941 meeting, 42 pp. Review plus research.

There is a distinct tendency in recent years toward the testing of metallic materials at elevated temperatures. Room temperature physical properties often fail to permit predictions on the behavior of alloys in service at elevated temperatures. The hot processing of metals and alloys has also been an incentive to a systematic study of physical properties at elevated temperatures.

Depending on the speed of the application of the load, such tests may be grouped as: (a) long-time, small load or creep tests; (b) medium-speed tests such as tensile, bending, static hardness; and (c) high-speed or dynamic tests such as notch-impact, tensile, bending and dynamic hardness tests. The development and application of the dynamic hardness tester have been almost exclusively European. This review and report confines itself to those dynamic hardness testers that have been applied to the testing of metals and alloys at elevated temperatures.

The same fundamental idea underlies both the static (Brinell, Rockwell, Vickers, etc.) and the dynamic hardness testers. A hard body (ball or cone) penetrates the object under test and since the indentation is larger the softer the material, it is related to the load applied and is taken as a measure of hardness. But instead of a slowly-applied load, the dynamic or impact hardness testing method uses a falling weight, a released spring or a hammer blow.

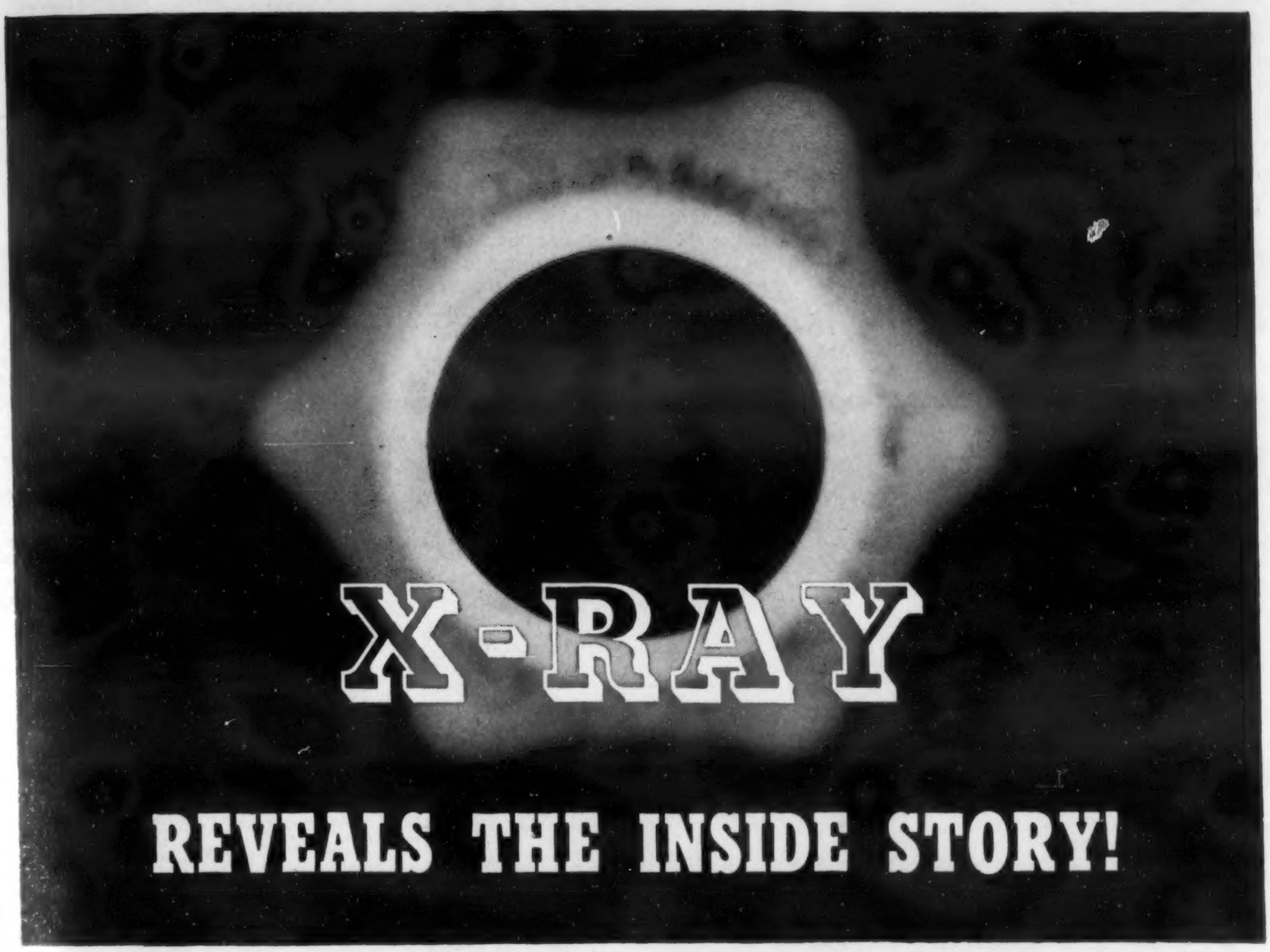
The static hardness test at elevated temperatures meets difficulties, which become the greater, the higher the temperature due to oxidation, flattening and structural changes of the ball, chilling of the test piece and continuance of flow of material under load. Although preheating of the indenting tool or the use of inert gases and of penetrators made of tungsten-carbide or single crystals of corundum eliminates some of the difficulties, the plastic flow introduces a serious variable, which is absent in the dynamic test.

The nature of the latter, furthermore, furnishes specific information not to be had by a static test. The conditions in forging, cogging and rolling seem to be more closely simulated by dynamic tests than by static. The same holds for the service conditions involved, for instance, in the pounding of a valve of an explosion motor.

The author reports some of his own experiments that illustrates the usefulness of dynamic hardness testing at elevated temperatures. For example, this is brought out in a striking manner by contrasting the behavior of a variety of steels in the same diagram.

The softening of a chromium-tungsten-silicon and a tungsten-chromium-vanadium die steel, of a plain and molybdenum-bearing 12% Cr rustless iron, and of two 18-8 steels with high carbon, high silicon and with low carbon, low silicon contents are shown in this way. Also included is a heat resistant chromium-nickel steel containing 26.1% Cr, 18.90 Ni, 0.94 Si and 0.11 C. This high alloy steel was tested over the entire temperature range of 500°-2200° F.

The dynamic hot hardness tests show that the resistance to plastic deformation does not necessarily decrease uniformly



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with rising temperatures. Retardations in the softening or even sudden increases in hardness may occur. The superiority of the 26-19 chromium-nickel steel at temperatures exceeding 1200° F. becomes apparent.

In spite of their greater initial hardness at low temperatures, the 12% Cr steels suddenly soften at about 900° F. The return to the condition of the annealed state is even more drastic with the die steels.

Alloys with low melting points or solidus points or containing eutectics are hardly useful for high temperature work. As the hardness curves approach zero at temperatures close to the melting point, the hardness curve of, say, a low melting high speed steel, must intersect the hardness curve of a mild steel. The room temperature hardnesses are obviously meaningless.

The dynamic hardness tester has been successfully employed in solving certain practical problems and has served as a valuable supplementary testing method in the study of physical properties at elevated temperatures. Standardization of the dynamic hardness test and its apparatus appears to be urgently needed if the present "art" is to become a "science."

Weighing critically the pros and cons of the different dynamic hardness testers, it appears that the Walzel machine (see METALS AND ALLOYS, Vol. 6, Jan. 1935, p. MA 21) offers the greatest all round advantages. Its rigid construction, the possibility of an accurate determination of the energy lost in the rebound, its simultaneous use for notch-bar tests and its adaptability for high-temperature work represent valuable features.

The Walzel machine employs a swinging pendulum, similar to the Charpy notch-bar tester, holding a 10-mm. ball at the striking face. A scale with a moving pointer provides a measurement of the unabsorbed energy lost in the rebound. The test is apparently performed outside of the furnace. The dynamic hardness is defined as: H_d=(impact energy—rebound energy)/volume of indentation. (4)

Tensile-Impact Tests

"RAPID TENSION TESTS USING THE TWO-LOAD METHOD." A. V. DE FOREST, C. W. MACGREGOR & A. R. ANDERSON (Mass. Inst. Tech.) *Metals Technology*, Vol. 8, Dec. 1941, T. P. 1393, 9 pp. Research.

One of the important problems in the design of structures and machine parts subjected to rapidly applied loads is the determination of the strength and ductility of the material itself under such conditions. Most past experiments have been made using notched bars in bending either with the Charpy or Izod impact machine.

While yielding valuable data on the effect of notches in the energy absorption of the material and on the condition of heat treatment, this form of test does not lend itself readily to a determination of fundamental stress-strain relations. More attention has, therefore, been paid recently to the tension impact test.

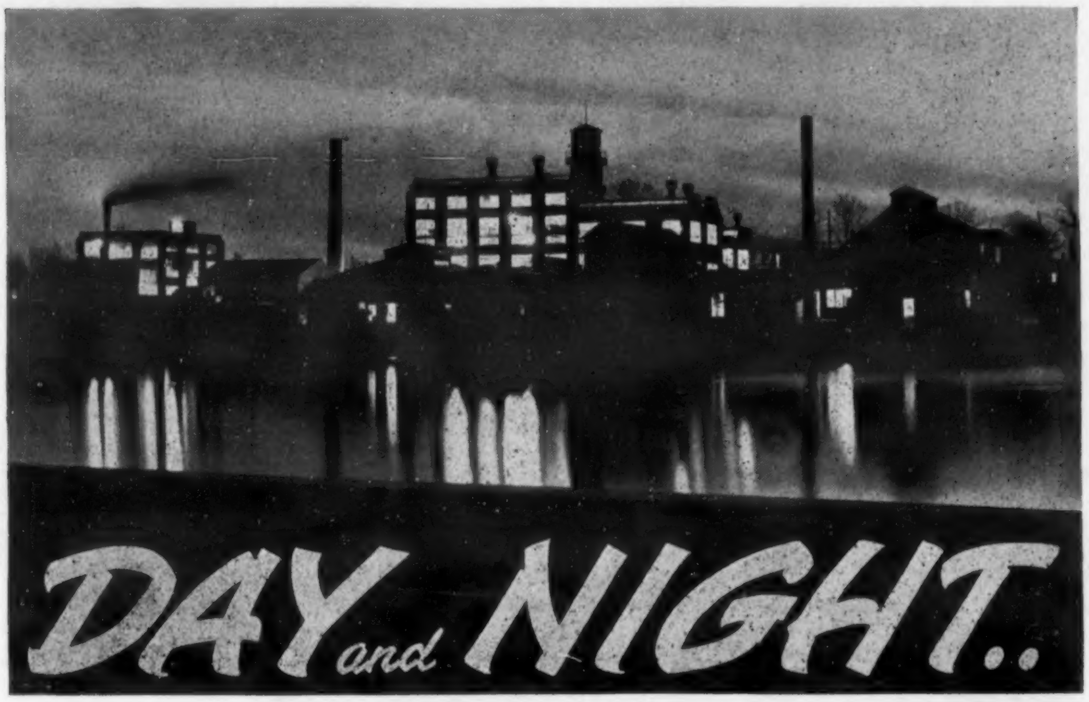
In most of the previous investigations on tensile impact-tests, when stress-strain relations were obtained under high rates of loading, it was the common procedure to determine stresses based on the original area and strains based on the original length. The advantages of true stress-strain curves in order to reveal the fundamental physical properties of the material for the tension test are numerous. Besides giving a better physical representation, the method has certain additional advantages in that the stress-strain curve so plotted becomes a straight line from the maximum load point to fracture.

The construction of such curves, however, while comparatively simple for the slow rates of loading customarily used in the tension test, presents certain difficulties for tensile-impact in that both loads and diameters are required throughout the test. The continuous measurement of test-piece diameters to fracture impact conditions offers considerable experimental difficulty.

In order to make it feasible to obtain true stress-strain data from initial yielding to fracture in the tensile impact problem, a two-load method was suggested some time ago. Briefly, this method consists in the scribing of a properly tapered tensile specimen by means of a diamond tool with fine circumferential scratches at different axial locations, measuring the diameters of the bar at these locations before and after the test, noting only the maximum and fracture loads during the test, and constructing the true stress-strain curve.

The method is complete in that it determines the true stress-strain curve from initial yielding to fracture. It lends itself particularly well to the impact problem, since the maximum and fracture loads are readily obtained, and it eliminates the necessity of measuring strains during impact.

Experiments are described in which the effects of the speed of testing on the true stress-strain properties of 4 different ma-



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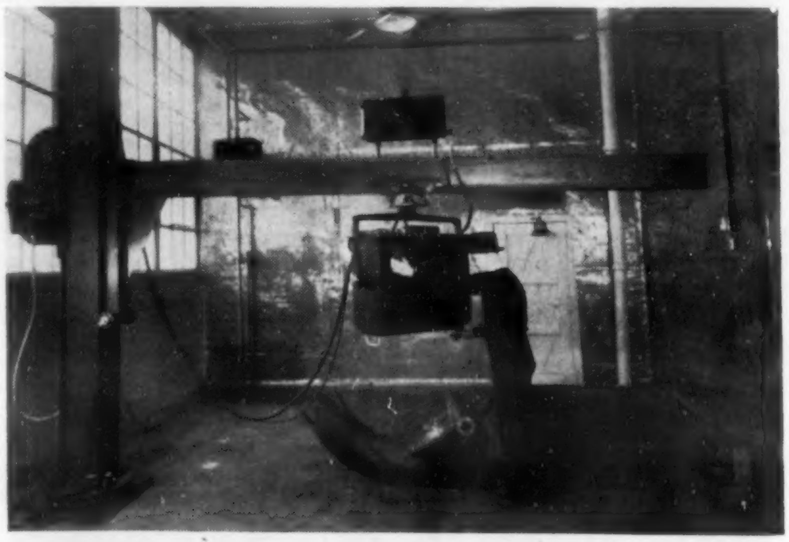

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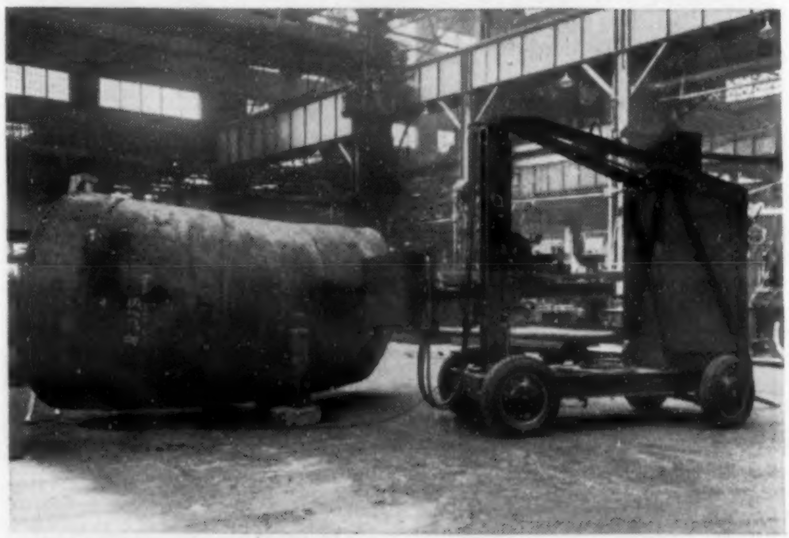

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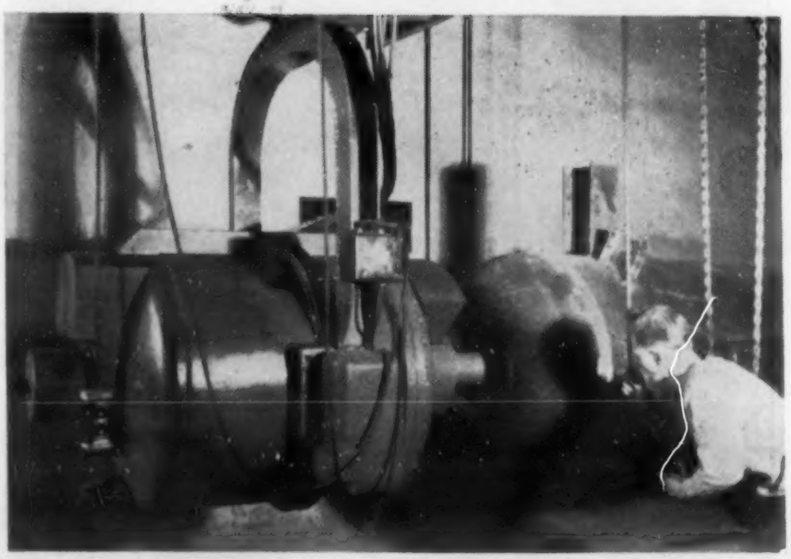

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terials were investigated by the two-load method. Both slow static tension tests and low-velocity Izod impact tension tests were conducted. True stress-strain curves were reported for each material.

A summary of the test data indicates for all of the materials tested (S.A.E. 1112, 1045 and 3140 steels and a brass) that the true stresses corresponding to the maximum load increased from 6.9 to 14.9%, the true stresses at fracture increased from 11.3 to 40.6%, and with the exception of the S.A.E. 1112, the true fracture strains increased from 3.1 to 23.3% for the different materials when tested under low-velocity impact conditions as compared to their static tension values. (4)

Fluidity Test for Cast Steel

"MEASURING THE FLUIDITY OF CAST STEEL." H. F. TAYLOR & E. A. ROMINSKI (Naval Res. Lab.) *Iron Age*, Vol. 148, Nov. 27, 1941, pp. 40-44. Descriptive.

The Naval Research Laboratory has developed a simple and quick technique for measuring fluidity. The problem has been to work out a test piece capable of measuring small variations in fluidity but which will faithfully evaluate maximum and minimum values resulting from extreme conditions of temperature and composition.

Several investigators have tried straight flow channels, but they were not satisfactory. Since the spiral mold for cast iron proved more promising as a test for cast steel, this type was tried after modifications necessary to adopt it to steel were developed. In order to standardize the method, sand grain size, pouring height, etc. had to be determined. All development work was done using a 300-lb. induction furnace.

The spiral test piece as adopted was found to be satisfactory for cast steel. Reference marks on the cope and the surface of the casting make it read directly. Variation in sand grain size from A.F.A. 53 to 123 showed no selective influence on the casting length. Molds made from bentonite banded green and dried sand, and cement sand gave equal spiral lengths. Thus, the test is not sensitive to any normal differences in various mold practices.

Within reasonable limits (variations from 2 to 10 in. above the pouring basin) the pouring height did not affect the reproducibility of the test. Varying the amount of aluminum added to 10-lb. spoon samples taken from an arc furnace indicated that 0.4 oz. was the proper amount for average heats of plain carbon steel in the unkilled condition. The time normally required to pour test casting is about 4 sec.

Composition has an influence on fluidity, depending on the amount of alloying element. A critical amount of oxidation was essential to maximum flow. Variations resulted in shorter spiral lengths for any given temperature. Temperature influenced the casting length.

Ordinary molding technique is used in preparing the molds. The steel is poured into the runner guide, builds up to the lower overflow level, runs into the pouring button and into the spiral. Another overflow ¼ in. higher empties into a catch basin. This arrangement prevents the ferrostatic head from changing more than ¼ in. The usual test weight is 8 lbs.

The standard technique adopted with a laboratory ½-ton 3-phase arc furnace proved very satisfactory. The mold is placed near the furnace door. The sampling spoon molds about 10 lbs. and is welded to a ¾-in. diam. rod 8 ft. long. A coil of aluminum 3/16 in. x 1/16 in. x 12 in. long wound on a rod is also needed.

When a test is desired, the spoon is warmed and slagged. A sample is taken from the center of the bath. A second operator stirs in the aluminum spiral for deoxidation. The spoon is dumped into the runner guide, and the spiral immediately solidifies and can be shaken out of the mold.

Through the use of this test, better steel and cleaner ladles have resulted. The small mold described is satisfactory for ½-ton or smaller ladles, but not for large bottom-pouring ladles, because of the rapid rate of flow of the steel from the nozzle. A large scale modification of the smaller fluidity test molds was made; the principles of flow are identical. Molds can be made of green sand, but dry sand is preferable when allowed to stand unused for several hours.

When making a test, the ladle nozzle is centered above the pouring reservoir and the mold is filled at the ordinary rate. It was necessary to place a sand baffle plate in front of the overflow into the spiral to prevent the metal from splashing into the flow channel.

These tests established the spiral mold as satisfactory for measuring fluidity of cast steel on the foundry floor. The mold is simple and economical, direct reading and compact. No careful leveling is necessary. For a given steel analysis and practice, it would be possible to calibrate spiral directly in temperature units with probable accuracy of ±77° F. VSP (4)

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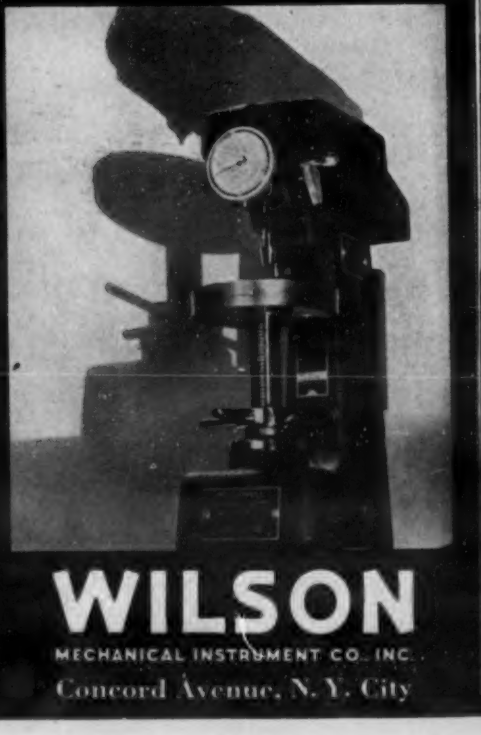

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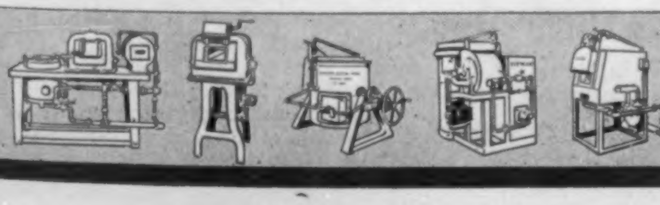

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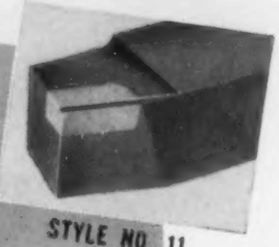
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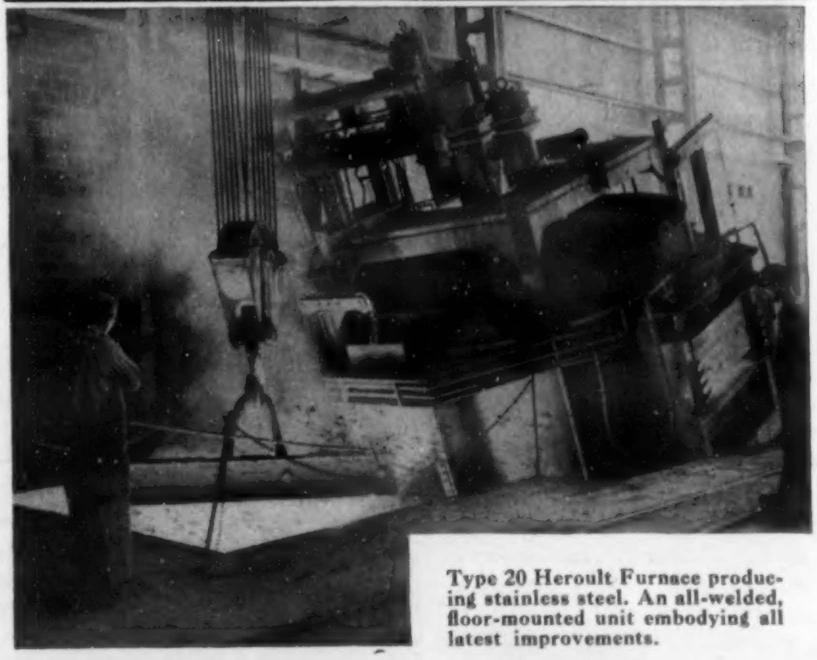
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FOR METALLURGICAL ENGINEERS

Pyrometry

PYROMETRY. *By W. P. Wood & J. M. Cork. Published by McGraw-Hill Book Co., New York, 1941. Cloth, 6¼ x 9¼ in., 263 pages. Price $3.00.*

The first edition of this book, published in 1927, was written because, in the authors' words, there was "no work which is organized in such a way as to be of great utility as a textbook for college students" and was written "with the needs in mind of the student as well as of the man more experienced in the uses and the theory of pyrometry."

In the present revised and enlarged edition the general character of the book has not been changed. Most of the questions, problems, and outlines of laboratory experiments have been retained (with different numerical values in the case of the problems) and many new ones added. The appendix consists of 17 tables as against 10 tables in the first edition.

The treatment of the fundamentals of thermometry is rather sketchy but will be found very useful to students and others who are unfamiliar with the bases of precise temperature measurements. A serious effort has been made to bring the material up to date, but the man actually engaged in industrial pyrometry who is looking for information in regard to detailed procedure should bear in mind that the book was written primarily for college students.

The book is well suited for use as a text-book for university courses in thermometry, and should therefore be welcomed because such text-books, at present, can be counted on the fingers of one hand.

The book contains a few statements with which the reviewer is unable to agree. One of these, of no importance in itself, should be mentioned in justice to the two men involved. On page 9 we read "The value 1549.2°C. [for the freezing point of palladium] reported in the monumental work of Day and Sosman has been shown to be in error." The basis for this statement is Schofield's work that gave 1554.4°C. ±1° as the value, but the difference can be traced to the use by the two groups of experimenters of different values for certain constants employed in the calculation, and Day and Sosman's values actually seem more nearly correct.

This edition is a decided improvement over the first edition, and the various subjects have been treated about as thoroughly as one could be expected to treat them in the allotted space.

—WM. F. ROESER

Materials Testing

MATERIALS TESTING. *By Herbert J. Gilkey, Glenn Murphy and Elmer O. Bergman. Published by McGraw-Hill Book Co., Inc., New York, 1941. Cloth, 9 x 11¼ in., 184 pages. Price $2.75.*

The authors of this laboratory manual have prepared the book after teaching experience extending over a period of almost 20 yrs. The arrangement of the material they have presented appears to be well suited to the teaching of a course in materials testing. To many critics, however, it will appear that insufficient emphasis has been placed on fundamental principles. Presumably the authors considered it better for such information to come from the instructor rather than from the text itself. The book consists essentially of a series of discussions of apparatus, tests, and properties of materials, without emphasizing basic principles.

The authors have placed major emphasis on concrete and covered quite fully the effects of various factors involved in testing this material. In the case of the metallic materials, however, there are relatively few instances wherein these effects have been as fully discussed. For example, modulus of rupture is discussed as a property of the material with only incidental inferences as to the effects of shape of specimen and type of loading upon the results obtained.

The design, control, and curing of concrete mixtures are discussed in considerable detail and illustrated with numerous specific practical examples. Comments on the fatigue properties of metals, on the other hand, are treated very briefly indeed.

The chapter on experimental aids in stress analysis is very interesting. It would seem, however, that greater significance should be attributed to the measurements of strains and deflections for actual structures or models, inasmuch as these measurements are the basis upon which all of the other experimental aids are based.

The supplementary questions distributed generously throughout the text are very good, and the answers given in the appendix present a comprehensive picture of the subject of materials testing. With proper emphasis on these questions and answers this book should serve as a very useful manual for a course in materials testing.

—F. M. HOWELL, R. G. STURM & R. L. TEMPLIN

Plastics

INDUSTRIAL PLASTICS. SECOND EDITION. *By Herbert R. Simonds. Published by Pitman Publishing Corp., New York, 1941. Cloth, 6¼ x 9¼ in., 385 pages. Price $4.50.*

This "quick" second edition (the first was published as recently as 1939) is a symbol as well as a record of the pace of development and extension of application in the field of industrial plastics.

The book is of very real interest to metallurgical engineers, for it is directed primarily at the "user or prospective user of industrial and structural materials" and in its writing considerable attention has been given to the complementary (sometimes competitive) relation between metals and plastics and to design problems involving both types of materials.

Two chapters cover the scope of the industry and plastics raw materials, and 10 present information on composition, physical properties, fabrication, design and application (including a section on "plastics in wartime"), future possibilities, etc. There are still other chapters on foreign practice, chemistry of plastics, trade names, etc.

In his chapter "Plastics and Metals," Mr. Simonds emphasizes the use of plastics *in combination with* metals rather than *as displacers of* metals in design. Recalling this magazine's June, 1940 article "Will Plastics Displace Metals?", he states:

> "On a tonnage basis, plastics of course do not yet threaten metals, but for a multitude of small products, plastics, in combination with metals under newly developed fabricating processes, offer a formidable challenge to metals used alone as well as to many other materials in combination. Further, due to the design possibilities of plastics and the new importance of appearance in utility products, it seems as if nothing could stop a rapid advance in the use of metals as a strength-aid to plastics or, conversely, in the use of plastics as an appearance-aid to metals. . . . The molder and the manufacturer of relatively small utility articles will do well to consider the combination of plastics and metals in their new designs and perhaps even to consider combining in

(Continued on page 352)

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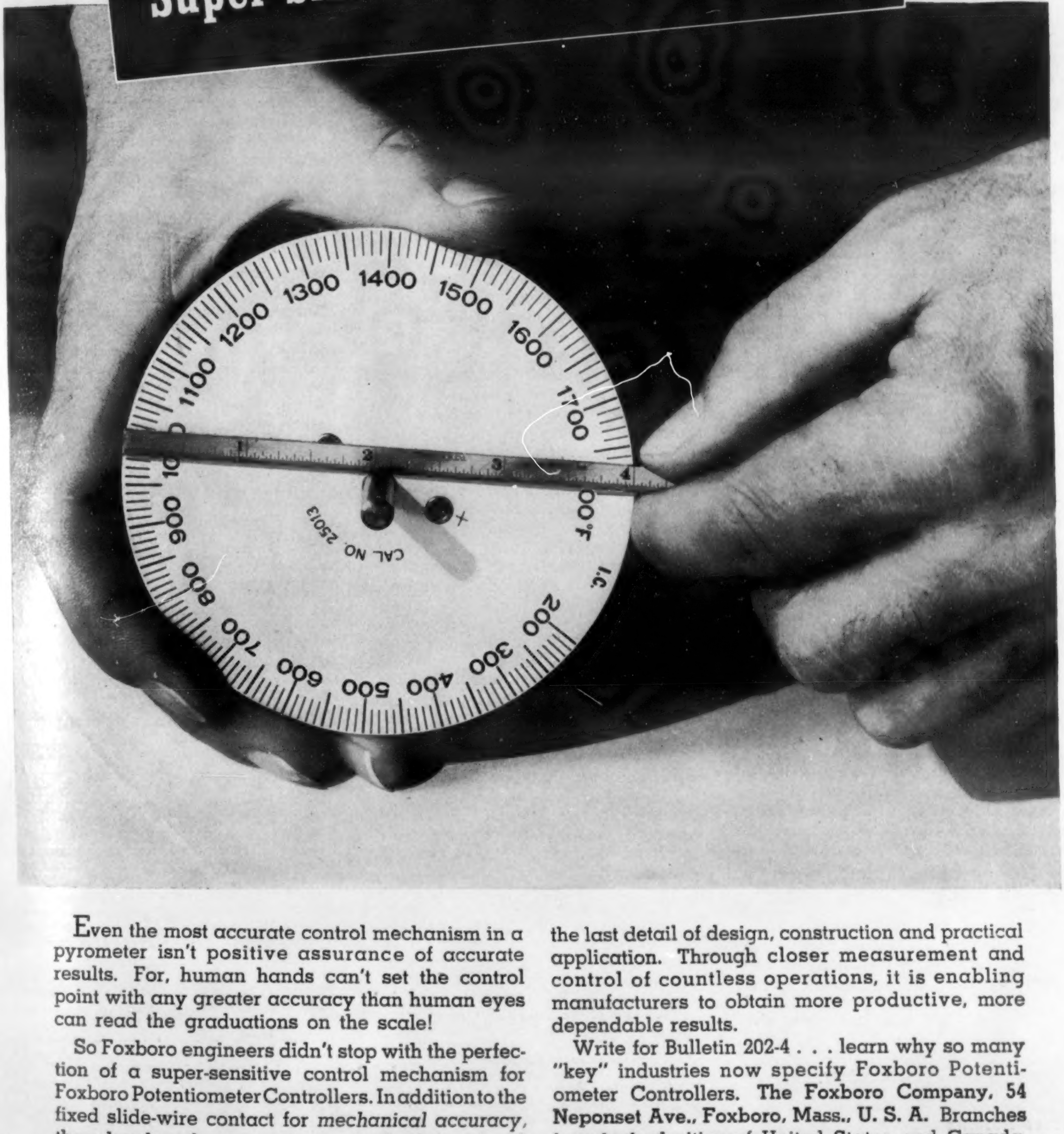

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Mr. Simonds believes that the plastics airplane is destined to supplant all other designs on the smaller planes of the future and cites several instances of regularly-operating planes that incorporate plastics-and-metal composite components or plastics-for-metals substitutions.

The book should be read and used by all engineers concerned with the materials and manufacture of industrial and consumer products.

—FRED P. PETERS

Photoelasticity

PHOTOELASTICITY. *By Max M. Frocht. Published by John Wiley & Sons, Inc., New York, 1941. Cloth, 6¼ x 9¼ in., 411 pages. Price $6.00.*

This volume, complete in itself, deals with the use of polarized light to show stress distribution, in two dimensions only, in transparent models. A second volume will deal with three dimensional problems. However, two dimensions suffice for most practical cases.

The book has definite value for certain important groups among this magazine's readers—particularly design engineers and testing engineers. To these it brings a wealth of very specialized information on technique and interpretation. Few "metallurgists" as such or "material engineers" are called upon to make photoelastic tests, since such tests, on transparent models, have nothing to do with the material of which an actual part is made, but show instead the stress concentrations due to the design.

But when the "designer" is hounding the "metallurgist" for an alloy that will stand up in service in some part whose design produces unnecessary stress concentration, the book will be a very present help, for by its illustrations the materials man can show the designer how bad the design is, and prove to him that it is up to him to correct it. Or when, as is often the case, the geometric design and material selection factors are the province of the same engineer, familiarity with this book will keep his right hand from spoiling the work of his left.

Although written by a professor, this is much more than a text book. It is of prime value to all metallurgical design engineers, and every metallurgist and materials man should go through it sufficiently to get the qualitative aspects well fixed in his mind. Few sources exist that give such striking evidence of the evil effect of notches.

—H. W. GILLETT

Press Working

PRESSWORKING OF METALS. *By C. W. Hinman. Published by McGraw-Hill Book Co., New York, 1941. Cloth, 6¼ x 9¼ in., 443 pages. Price $4.00.*

Mr. Hinman's new book is a very complete story of the various phases of sheet metal operations. Early in the book he gives a comprehensive outline of the different types of power presses and their uses, as well as a discussion of the factors determining the size and kind of press required for individual jobs. A later chapter is given over to the construction and application of the many press accessories such as feeds, coil holders, cushions, etc.

One interesting chapter explains the many factors involved in selecting suitable metals to be fabricated by the different press operations. The physical properties of ferrous and non-ferrous metals and their workability in dies are well presented and should prove particularly valuable to press shops.

Many metal-industries engineers will wish that the discussion of the behavior of nonmetallic materials in dies could have been expanded to cover some of the newer plastic materials but it is probable that there are not many data available as yet.

A chapter entitled "Mathematics for Tools and Presses" should be of great help to pressed-metal engineers or die makers because in it has been concentrated a great number of pertinent formulae not available in any other one book. These formulae are understandable and easy to use, and the many tables and diagrams supplement the text admirably.

Some statements of the author concerning the metallurgical changes occurring during plastic working seem to differ from those of such authorities as Zay Jeffries and E. V. Crane. However, the volume is obviously intended to feature engineering rather than metallurgy and the discussion of die construction and operation are probably as comprehensive and informing as can be found in any recent book. The extensive explanations and detailed drawings of the various types of dies, die construction, die accessories, scrap layouts, and press operations are quite practical and should prove very valuable, particularly to beginners.

This book will be a welcome addition to the library of any one concerned with press working of metals.

—W. M. EVARTS

Diffusion in Metals

DIFFUSION IN AND THROUGH SOLIDS. *By R. M. Barrer. Published by The Macmillan Co., New York, 1941. Cloth, 5¾ x 8¾ in., 464 pages. Price $4.50.*

This is a general treatment of diffusion in solids. In indicating the scope of this important book, the reviewer can do no better than to quote the outline given on the cover:

> A study of the permeability of materials to solutes, and of the diffusion constants of solutes within them. The author's aims in this book are: to keep a balance between experimental methods and their mathematical and physical interpretations; to provide lists of permeability and diffusion constants for ready reference; and to outline current theories of processes of permeation, solution, and diffusion.
>
> Chapter 1 gives a number of solutions of the diffusion equation suitable for treating the various problems that arise in the course of the study.
>
> Chapter 2 surveys the different types of gas flow in capillary systems.
>
> Chapter 3 deals with gas flow through glasses and crystals.
>
> Chapters 4 and 5 discuss the processes of diffusion of gases through and in metals—a subject of growing technical application.
>
> Chapters 6 and 7 describe the phenomena of conductivity and diffusion of ions and atoms in ionic lattices and metals.
>
> Chapter 8 describes surface diffusions.
>
> Chapters 9 and 10 discuss the problems of gas and vapor flow through diffusion in organic polymers, usefully collecting together a large number of constants for systems of technical importance.

This subject has made very rapid strides in the past decade and has been in need of adequate summary. The present book is easily the best yet published, and apart from its high scientific quality, it makes intensely interesting reading, an aspect which authors too often neglect; it is more complete than the comparable volumes by Seith and by Jost, and is usefully critical. The treatment of the mathematics of diffusion is especially valuable; the discussion of the diffusion of gases in solids is unexpected in books on this subject, and welcome.

Inasmuch as so many metallurgical processes proceed by the operation of diffusion processes, the book is important to the metallurgist and of basic interest to the metallurgical engineers; the reviewer has made it required reading in a graduate class in physical metallurgy.

—R. F. MEHL

Other New Books

A.S.T.M. STANDARDS ON ELECTRICAL HEATING AND RESISTANCE ALLOYS. *Published by American Society for Testing Materials, Philadelphia, 1941. Paper, 6 x 9 in., 103 pages. Price $1.25.* Specifications and test methods for resistance alloys, radio tube and lamp parts, thermostat metals, etc. as prepared by committee B-4 of the A. S. T. M.

SPECTROCHEMICAL ABSTRACTS. VOL. II: 1938-1939. *By E. H. S. van Someren. Published by Adam Hilger, Ltd., London, 1941. Paper, 6 x 9½ in., 38 pages. No charge.* References and very brief topical abstracts of the 166 papers and books published in the approximate period indicated extend the total no. of references in Vols. I and II to 394. Vol. I (reviewed in Metals and Alloys, Vol. 9, Oct. 1938, p. MA 631) covered the period 1933-1937.

BOOKS, PUBLICATIONS AND PATENTS OF BATTELLE MEMORIAL INSTITUTE. 1929-1940. *Published by Battelle Memorial Inst., Columbus, Ohio, 1941. Paper, 6 x 9 in., 47 pages. Free upon request.* More than 500 references, arranged chronologically, of articles, papers, patents and books on metallurgy, chemistry, ceramics, etc., with a useful index.

A.S.T.M. STANDARDS, 1941 SUPPLEMENT. PART I—METALS. *Published by Am. Soc. for Testing Materials, Philadelphia, Pa., 1941. Cloth, 6¼ x 9¼ in., 597 pages. Price $3.00.* Contains the newly adopted and revised "standards" and the new and revised "tentative standards" in the metals field adopted since the first supplement (to the 1939 Book of Standards) approved in Nov. 1940.

THE COMMERCIAL MARKET FOR PEARLITIC MALLEABLE CAST IRON. *By Donald L. Boyes. Published by Dept. of Business & Engineering Administration, Mass. Inst. of Technology, Cambridge, Mass., 1941. Paper, 6 x 9 in., 82 pages. Free to interested engineers.* An unusually interesting and valuable monograph. Reviews the proprietary pearlitic malleables, their commercial statuses, the marketing factors and needs, competition with steel casting and forgings, the dominant position of the engineer in the market, etc. For a critical review of the book, read the editorial "Pearlitic Malleable Sanely Considered," in this issue.